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THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

PROCEEDINGS.

SESSION 1901—1902.

VOL. XVII.

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THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

SESSION 1901—1902.

The first Meeting of the Session was held at The Institute, Dudley, on Saturday, the 28th September, 1901.

THE PRESIDENT (Mr. WALTER SOMERS) occupied the chair, and there was a large and representative attendance.

The minutes of the last Annual Meeting and of the visit to Glasgow Exhibition, were read, adopted, and signed.

The following were elected members of the Institute :—Messrs. J. A. Parker, Arthur Lynn Scotson, Robert Johnson, T. W. Moseley Jacks, Frank Moore, Robert Buchanan, David Rushworth, Charles Henry Wall, William Henry Taplin, Haywood Hartland, and C. R. Yates.

Mr. WILLIAM BROOKS : As this is the first meeting of the Institute since the death of President McKinley, I think we should pass a vote of sympathy with the American nation on their loss. It is indeed deplorable that President McKinley, who had worked his way up to such a high position, should be suddenly deprived of his life in such a horrible way. I therefore propose—

"That we sincerely sympathise with the American nation in the loss "they have sustained by the death of the late President McKinley, and "especially with Mrs. McKinley in her sad bereavement, and that this "resolution be transmitted to the proper quarters."

THE PRESIDENT : I am quite sure that this Institute, and everyone throughout Great Britain, most sincerely sympathises with Mrs. McKinley and the whole American nation in the loss they have sustained.

The vote was unanimously agreed to.

THE PRESIDENT, upon rising to deliver the following inaugural address, was received with loud applause. He said :—

ADDRESS BY THE PRESIDENT

(Mr. WALTER SOMERS).

It seems to have become a custom for your President to deliver an inaugural address, and while there are many matters of great importance upon which I might dwell, I have great difficulty in selecting such subjects as will not only interest you but will be of benefit to our Institute.

Before going further, I cannot help alluding to the great loss this country has sustained in the death of Her Most Gracious Majesty the Queen and Empress Victoria, who ruled over us for a longer period than any other monarch. There is no doubt that she was venerated, beloved, and trusted in every part of the world, the admiration of all nations and the pride of our own. During her reign the Iron and Steel Trades have made most rapid strides, which must be attributed in a great measure to the good government administered so wisely and prudently by Her Majesty.

I think I might dwell upon some of the great improvements and inventions during her reign.

I am afraid my experience of iron and steel making is so limited that I shall have great difficulty in making my address interesting. I have worked iron and steel all my life, and will try to bring to your notice some of the improvements during the last century; and, although many of you may be fully acquainted, there may be some present whom it will interest.

Some years ago I spoke at one of our meetings of the great waste of fuel in ironworks; and although this state of things is somewhat improved upon, I think we must all admit that there is great need of further improvement, especially in South Staffordshire.

Now let us go back a hundred years—at that time it took about 8 tons of coal to make a ton of pigs, and a furnace turned out about 20 tons per week. The whole of our annual production did not exceed 200,000 tons. At this time the total amount of bars and other wrought-iron was about 60,000 tons per annum, and about 200,000 men were employed. There is no doubt that in the past, as in the present day, fuel was a great factor in ironmaking, therefore demanding an economical use of it. In 1820 I find the quantity of coal got down to four tons per ton of pig iron, and ten years later, in 1830, it was three tons. At this time the

make per week had reached about 80 tons per furnace. In 1828 hot air was introduced, and although many were prejudiced as to its advantages, it gradually worked its way so that in ten years' time the make of pig iron was doubled.

The consumption of fuel in 1860 was about 27 to 28 cwts. of coal, made into coke, per ton of iron.

The hot-air was introduced into blast furnaces by Neilson, and many people consider this one of our greatest inventions. Neilson was a great student in the College at Glasgow, and a very great advocate for technical instruction, of which I shall speak later.

In 1845 the make of pig iron increased to 100 tons per furnace per week, and year after year there has been great increase in the quantity produced with less fuel to produce it. But about puddling furnaces—I am afraid we have not advanced at the same rate as we have with blast furnaces—in some works they have scarcely advanced at all. The mill furnaces in many cases are not as economically worked as they ought to be, at any rate not in the same proportion as the blast furnaces. I am quite sure there is great room for improvement by us all, and the only way to lower the price of fuel is to adopt more economical furnaces and use less; more especially in the use of slack instead of coal, and to utilise all the fine slack which is now thrown away down pit banks.

In 1842, Nasmyth introduced the single-action steam hammer, which I may say is more in my line than blast furnaces. It is wrong to suppose that the idea of steam hammers originated with Nasmyth, as such hammers had been proposed by James Watt in 1784, and again by Deverell (in nearly its present form) in 1806; and I may say that in some parts, such as the fastening of the piston-rod in the tup, by Nasmyth, is the best method, and undoubtedly fewer rods are broken than with any other mode of fastening. Moreover a much smaller rod can be used (for instance, my 12-ton hammer has a rod only seven inches diameter), thus giving more steam room in the cylinder.

Since then steam was introduced on the top of the piston of hammers, giving a double action. This has added very much to the value of steam-hammers.

We have heard a good deal lately of hydraulic presses, and there is no doubt more will be heard of them. But the enormous expense of putting down a press, furnaces, traveller, &c., to do what can be done with a 12-ton hammer, runs into a matter of £30,000. People are very careful of going to such a heavy outlay, as in slack times interest of money soon runs up, and no one cares to have capital lying idle; at the same time the labour for presses is easier to get than for steam-hammers, as a far less skilled man can work at a press and make difficult forgings; but to make such forgings sound and to correct size under a steam-hammer requires a skilled man, as an inferior man not only makes

the forgings the wrong size but spoils the quality of the material; therefore this expensive labour will compel us to put down presses to enable us to successfully compete with foreign countries.

No doubt time has proved that Neilson, the inventor of hot blast, was singularly in advance of his age. We all know how much the success of Continental and American manufacturers is to be attributed to the judicious expenditure of capital in the careful planning of their works with a view to economical production, and much more to the better education of their workman, as compared with that which was obtained by our workmen. Take, for instance, the time when this Institute was founded. There was no system of national education. In 1870 Mr. Forster's Education Bill was passed, when elementary education was made not only universal, but compulsory in this country. But although elementary education was provided, there was no provision for scientific, or, as we now say, technical instruction, bearing upon the great and varied industries of this country and in which our artisans are engaged. But happily, in 1889, the Technical Instruction Act was passed, giving Municipalities the power of levying a rate for this purpose; and further, in 1890, a great help was given to the movement by allocating, under the Local Taxation Act (Customs and Excise) considerable funds to the County Councils, with power to devote them as most desirable to Technical Instruction.

The great value of this instruction is its importance in enabling the country to hold its own in its race of competition with other countries, in the more intellectual conduct of its industries. In this respect it is difficult to over-estimate its value, and, although the artisan class as a whole do not realise to its full extent the value of this technical instruction, there are many who have made good use of it, the numbers annually increase, and a great deal of good work has been accomplished. All this had been going on in Germany, Austria, and other countries long before ours; and it is not pleasant to allude to other countries as being wiser and more generous than our own, especially when those countries are poor in comparison with ours. It is the pride of Englishmen to make our country maintain its position in the world. Therefore, this technical instruction came none too soon; and it is for an Institute like this, composed of men who come in daily contact with so many of our artisans, to instil into their minds and make them realise the great advantages and value of technical instruction. For, depend upon it, if our workmen do not grasp the opportunity given to them and make themselves more proficient, they will find foreigners doing their work. It is superiority of work added to the quality of material which commands the trade. Talent is not ruled by wealth or social privileges; but by perseverance and making use of the facilities given, which facilities at the present time are very different to what they were thirty years ago. Great men, such as Arkwright, Maudsley, Watt, Stephenson, Neilson, Bessemer, and Siemens rose from small beginnings,

and there are great men in Parliament, who, only by study and making use of the facilities afforded them, have attained their high position. Members of this Institute can do much for the Iron and Steel Trade by impressing upon the apprentices and young workmen the value of the advantages placed within their reach by Technical Schools. You will find that in a few years it will bring marked results in the intelligence which is being brought to bear upon our industrial occupations; also that the wider intellectual interests will tend more and more to that spirit of reasonableness and usefulness which is such an important desideratum in the relations of labour and capital.

I have no doubt my predecessors have gone more especially into the nature of our iron ores, the making of iron and steel and machinery for manipulating same. I think it fitting to dwell upon the training of the worker as being a not less important element in the question of successful production, seeing that the elimination of ignorance and unreasonableness is no less a factor in the problem than the removal of phosphorus from our steel or impurities from our fuel, and it is of value both commercially and intellectually. This is why I speak to some length on the subject.

Labour difficulties have proved a great hindrance to our trade from time to time, and tbe more we look back upon this, the more we find that education has helped the principles of conciliation and arbitration, has reduced the proportions of those industrial wars (ruinous alike to masters and men), which took place in by-gone days, and, in fact, replaced the barbarous methods of strikes.

The second half of last century began with an event of great importance, for in 1851 was the great Exhibition which told of our industries, and opened to all nations the knowledge of our capabilities. At that time we produced 2¼ million tons of pigs, so that our annual production had increased from 200,000 to 2¼ millions in fifty years.

It was in that same year that His Royal Highness the Prince Consort, by his great wisdom, projected a scheme of instruction in the shape of an Institution which developed into the Royal School of Mines; and no doubt, had he lived and his ideas been carried out, technical instruction in this country would not have been so long delayed.

In the year 1856, Bessemer introduced us to his process of making steel. At this time the make of steel in this country was 50,000 tons per annum, and some of it cost £75 per ton. As we all know our people were slow in taking it up, for in thirty years the make of Bessemer steel only reached 1½ million tons; but after that more spirit was infused into steel making, so that by the end of the century it reached many millions of tons, and the make has now so increased that Scotland alone this year will produce as much as all Great Britain did two years ago.

There is no doubt that South Staffordshire is severely handicapped by the arbitrary conduct of the railway companies. In America, manufacturers are met in a most liberal spirit by the railway companies; but here there are cases of manufacturers removing their works to the coast or they would have to face the alternative of giving up business altogether. Some time ago it was said there was going to be a large waterway from Liverpool to London, Birmingham, and Gloucester. If this were done, you would find South Staffordshire could hold its own with Scotland, America, and Continental countries. But as long as we submit to the railway companies' excessive charges, so long shall we be handicapped for foreign orders.

Owing to France, Germany, and other Continental nations being divided, we are apt to speak of them as though they were far distant from each other; but if you will compare them with the distances traversed in the United States, they are close neighbours.

Of late, we have imported and are inporting large quantities of iron ore from Spain and the Mediterranean coast. This ore is carried by sea in many cases the whole distance, and for special ore we have gone as far as the Caucasus, India, Brazil, and Chili. By the people of the United States these would not be considered extraordinary distances, as in their country materials can be carried by rail or water at very much lower rates than ours. No doubt the great advantages Americans have over us, and the wonderful competition with the European Continent, are due to the advantages given to these countries by rail and water carriage. As an instance, they carry fourteen tons of fuel in a truck for twopence per ton, including truck hire. Why should not Great Britain have the same advantages in freight on railways as the Americans, or even as they have in Belgium or Germany? This is a matter of the greatest importance to this country. If we could have the same advantages we could then hold our own in the markets of the world. The way in which railway companies hold together throttles trade, and no doubt Parliament will have to seriously consider the matter and make it an Imperial question. Our great population is increasing, not only in numbers, but in knowledge, and the time is coming when we shall awake to this fact, and demand from our representatives in Parliament a promise to insist upon its being made an Imperial question.

The Continental railways are principally held by the States whose great object is to use them as far as possible for the purpose of developing the resources of their country; in fact, their low rates for fuel, etc., enable them to compete successfully and give them great advantages in the markets of the world.

If railways were to increase the size of their wagons for coal and raw material, it would facilitate this. They used to carry only five to six tons, they have now got to eight to ten tons; but if they were increased

to fifteen to twenty tons, they would be able to carry that extra quantity for very little more cost, and so give the advantage to freighters. Great efforts are being made by manufacturers to reduce the cost of manufacture, therefore, there should be adequate reduction in the transport of fuel and material, both finished and in its raw state, to enable this country to maintain its hold upon the markets of the world.

It is, therefore, for the railway companies to do their part, as they are as interested in the development of the chief sources of their traffic as the capitalists.

These last few years we have experienced what the Americans can do in competition, and Japan will have to be reckoned with. There are about 200,000 miles of railway in the United States, whilst in Great Britain we have only about 20,000. Nearly all these are conducted by private companies. Now, if the United States carry fuel and ore at such a rate as enables those using it to successfully carry on their trade, and at the same time develop the resources of their country, why should not our railways do the same? We are quite sure the Americans do not work for nothing. Great Britain being the great centre, its insular position must give it great advantages, and if railway companies lowered the rates it would assist in our maintaining the position we have attained as the great commercial centre of the world.

We cannot doubt that in the future, fields of enterprise in the direction of railway work will be opened out to a great extent, and indeed far beyond that we have hitherto experienced. Ten years ago, Asia had only 20,000 miles of railway, and to-day there are not 10,000 miles of railway in Africa, to which Continent at the present time all eyes are turned in the hope and expectation that the splendid energy and indomitable courage and perseverance shown by our fellow countrymen on that great undeveloped Continent will find their reward; and, shocking to our feelings of humanity as this terrible war has been, there is no doubt that out of the temporary evil of war and bloodshed may come the permanent good of opening up the new country to the advantage of modern enterprise. Not only in opening up new markets for our manufacturers; but in bringing civilisation and enlightenment into the dark places of that great land.

We are doing a large trade with our Australian colonies, and the last two or three years have shown how closely allied we are to them, so that our future as regards trade with these colonies is very bright and cheerful.

We then get to China with its 4½ millions of square miles, and say one-twelfth of the land surface of the globe and its immense population of 300 millions of people, that country has scarcely any railways; whilst Japan, which until recently was almost unknown, has awakened

to the knowledge that they were behind the times, and these last few years has made strenuous efforts to be up alongside western countries; and our own country has been the recipient of very large contracts for iron, steel, and machinery. These contracts are now being executed in different works in England and Scotland. But the time is coming when the people of Japan will become competitors instead of customers, as they are erecting large works and dockyards of their own. They have had many of their engineers and other intelligent men spending their time in our works and dockyards, and no doubt the knowledge these men have gained will assist them in competing successfully with us, besides which, they get much cheaper labour and longer hours than we do.

This brings me to the labour question, which in this country is becoming very serious. Competitors in other countries work much longer hours than our men. This gives them a great advantage over us. Other countries of late years have made such rapid strides that we feel we cannot afford this continual reduction in the hours of labour. For many years, England and Scotland were, to all intents and purposes, the workshops of the world. In the development of their natural resources we were ahead of all foreign competitors; we were supplying to a great extent the requirements of the newly awakening enterprise of every quarter of the globe, so that it will be well for our workmen not to ask for shorter hours until our competitors in foreign countries reduce their hours. It is right that labour should receive its fair share of remuneration, and should have a fair day's wages for a fair day's work; and there is no one who does not mark with satisfaction the greatly improved condition of workmen attained during our memories; but, at the same time, this reduction in the number of hours adds to the cost of production and tends to diminish the bulk of trade. The State would do well to foster by every wise means in its power the trades upon which the existence of our Empire depends. No one can deny, and I think all of us who are in the trade are of the opinion that State action may be more profitably employed in the opening out of every possible means of new and more extended fields of enterprise wherever they can be found in this great Empire, whether it be India, Africa, Australia, or elsewhere, than in imposing regulations which tend to increase the cost and restrict the output of our home industries. Workmen should bear in mind that foreigners are equipped with works which are up to date, natural resources as to material and fuel, advantages in railway rates, and longer hours than we have; so that our position of absolute superiority which we once held has vanished, and when to the development in these foreign countries of their own resources is added the barrier of protective tariffs, which not only foreign countries but our own colonies have imposed in order to foster their own industries, it is no wonder that the problem of holding our own in the universal struggle becomes more accentuated every year.

To such an extent has skill and knowledge been lavished upon our manufacturing process, and in spite of all our improved machinery and appliances, not forgetting the great advance in chemical research, we find some works not fully employed owing to the difficulty in getting a remunerative price; but, severe as competition is, we cannot afford to neglect any means to secure excellence of quality and economy in producing it. The time seems to have gone by when manufacturers can hope to amass large fortunes as in the past, when at that time we were the pioneers of the great mechanical industries, and had practically the whole trade of the world to choose from.

Perhaps nothing has tended so much to check enterprise as the reckless manner in which some businesses have been thrown on the market all over the country. This has caused a feeling of insecurity and uncertainty, and although there never was a time when so much accumulated capital was waiting for employment, owing to the unstable conditions of the Limited Liabilities' Act (certainly it has been improved by this Parliament), capitalists at present prefer in many cases securities yielding 2½ or 3 per cent., where there is some assurance of stability, to the more precarious trade investments in public companies thrown on the market by unscrupulous promoters of public companies.

I have been saying a good deal as to there being more economy in working, less fuel used, and better machinery. Surely the railways have effected great economies both as to fuel and working, and we know that they have more volume of business. Yet railway rates are no lower, but in some cases they are even higher, and every advantage is taken to extract as much as possible from those who are their very existence.

What astonishes us more than anything is that the railway companies actually put down works to manufacture their own material. Many years ago the Government of the day were severely censured by many people for dismantling some of the dockyards, and instead of building the ships and making the machinery in their own yards, orders were distributed amongst the traders of the country. The result is that large orders are being placed in different parts of England and Scotland, and many of us get back a little of the money we pay in taxes. But in the case of the railway companies, they largely manufacture in their own yards, and had it not been for a very determined action by certain traders a few years ago, the larger railways would not only have supplied their own requirements, but have been actually our competitors. I say all honour to those who prevented such arbitrary conduct, and it now rests with traders to resist such encroachments. Railway companies are carriers pure and simple, and we ought to resist attempts to be more than that; especially when they give their customers no advantage in rates, in spite of the profit they make in their works, which works did not exist in days gone by, at any rate not to the extent they do now.

In our district many times large orders have been lost for the sake of half-a-crown per ton in getting the material to the coast ready for shipment, when, but for the arrangement which the railway companies have for a fixed rate—which rate is most exorbitant—those orders might have been obtained, simply by the trader and the railway company agreeing to divide the half-crown per ton. But no, the trader must either lose the order or sacrifice the half-crown, and as he cannot afford to do this, the order is lost.

We have two railway companies in our midst, the London and North Western and the Great Western. The London and North Western's works at Crewe make practically all the material they use. The Great Western have works at Swindon, but they do not roll their own material, a great deal of which, I am glad to say, is supplied by South Staffordshire, and we should acknowledge this by giving the Great Western Railway as much traffic as possible. By so doing we shall show that we disapprove of the railway companies being large manufacturers.

It is surprising that the consumption of steel has grown so enormously and is still increasing; but it is accounted for by the enormous quantities used in ship building and in the construction of large buildings—more especially in America, where large buildings fourteen to sixteen storeys high are erected, and large hotels, which buildings will take as much as 10,oco tons of steel in one block. It is remarkable the great increase of steel used in our collieries, railway wagons and other ways, where until late years timber was used instead.

There have also these last few years been great advances in labour-saving machinery, and it is especially interesting to see the enormous ingots rolled down into blooms with scarcely any manual labour. I recollect one of the Presidents of the Iron and Steel Institute a few years ago saying that at the rate labour was being saved by machinery, there would be a great number of men thrown out of work; but quite the contrary has happened, the men have been better employed since then, and there is no doubt that had we not seen and realised the value of such machinery, we should have been far behind in the race of competition, indeed, so severe has competition become that we cannot afford to neglect any means by which excellence of quality and economy of production can be secured.

I think we may say that trade is fairly good at the present time, but for how long no one can tell, so that it behoves all of us to put our house in order. Perhaps some of the questions I have brought forward to-night may afford food for thought, and indicate a state of things which is important; so much so, as to point the moral that neither capital or labour can afford to do anything to hamper trade. There are many undeveloped resources of the world, waiting for the enterprise of capital, to provide fields of labour far greater in extent than

any of which we have heretofore had experience, and we may be sure that the day is close at hand when those activities will be called upon to a very great extent. We must remember that we are small in number compared with those who are competing with us for the trade of the world, and there is no time to make great mistakes which would compel us to retrace our steps; at the same time we must go forward in wise expenditure, both as to economy in fuel and saving of labour, or we shall probably find out, when too late, that a good deal of our trade has left us and gone into the hands of more enterprising nations.

Well now, gentlemen, in conclusion, I may say I am sorry not to have had a more lengthy and interesting address to give you to-night. I was abruptly cut off by bad news of my son, but that trouble has been lightened very much by the deep sympathy shewn by so many friends, and for which I am deeply grateful.

Mr. J. W. Hall: I am sure we have all listened with the greatest of pleasure to the very interesting address given to us by our President, whom we are all very pleased to see amongst us, and who, I am glad to see, has taken up his position as President in a practical manner by bringing us many new members. The President has called our attention to what, undoubtedly, we have to look to in the future, by turning our thoughts in the direction of probable increased competition. Formerly, if other nations wanted machinery, or iron, or steel, or even textile fabrics, they had to come to us. But now, I am sorry to say, the position is rather the other way for we have to go to them. Most of you know the difference between having ten people anxious to buy what you have to sell, and finding ten people anxious to sell what you have to sell. That is our position to-day, and that position is likely to be accentuated day by day, as the Governments of other countries are encouraging their own industries by tariffs. Whether in the end this policy benefits the country which adopts it or not, there is one thing perfectly certain, namely, that it hinders us. The closing of markets in all directions which we have been experiencing is a very serious matter for us all. And we have seen that this artificial Protection does enable the cost of production to be reduced. We see what the position in America is to-day. America could not possibly produce to-day at present prices if it were not for the fact that her home industries have been protected by her Government. Once established, these industries cannot be stopped. There they are and you have to deal with them, and the President has wisely recognised that position. I should like to refer to the recent bereavement our President has experienced in South Africa. We appreciate at its true value an address written under such sad circumstances. I am sure, therefore, you are all with me when I wish to thank him for his address, and at the same time to say how deeply we sympathise with him in the loss he has sustained abroad.

Mr. Alex. E. Tucker: It affords me great pleasure to second the vote of thanks. I second it from two reasons. Firstly, because of the intrinsic merit of the address; and secondly, because our President has written it under the shadow of peculiarly sad bereavement. Only a few weeks ago Mr. Somers lost a dear daughter, aged 25, and this was followed last week by the death of a son in South Africa, where he had gone to gain health. Our especial thanks are, therefore, due to our President, for his loyalty to our Institute by writing any address under such circumstances—circumstances which I submit would have dismayed most of us.

It is not usual, I am aware, to discuss the addresses of our Presidents, but I may, perhaps, refer to one point, namely, the ever-recurring one of technical education, and in other departments than that of iron and steel manufacture, it appears to me that we have little to fear. One only has to go to some of the splendid Technical Schools now established in various parts of the kingdom to see what an excellent regime is attending these schools. It is to me a great pleasure to go to the Birmingham Technical School, as I frequently do, and to note the class of young fellows working there. The effects of such schools are already being shown in works not only in Birmingham but also elsewhere. Go to such works as Archdale's, Ward's, Platt's of Oldham, or the like establishments, and you will see that the status of the men is one of high technical ability, and one in which we may place our confidence. In iron and steel manufacture it appears to me that general rather than technical education of the workmen is our immediate want. In conclusion, I have great pleasure in seconding the vote of thanks to our President for his address, and especially so under the cfrcumstances I have named.

The Mayor of Dudley (Mr. E. Grainger, J.P.): It has given me much pleasure to listen to this excellent address from Mr. Somers, and I tender him what little sympathy I can for the unfortunate conditions under which he has written it. With regard to technical education in Dudley, unfortunately all that can be said is that when things are darkest then they are nearest a better state of affairs. I hope that we shall shortly be able to put educational matters upon a stable basis. I am very pleased to have been able to support the vote of thanks.

Mr. Walter Jones: In one part of his address the President says the only way to lower our fuel expenses is to adopt more economical appliances and so use less fuel. That has been done for many years, and it struck me on hearing this, that the Government ought to take the collieries over if the colliery proprietors expect an unreasonable or undue profit. I can endorse a good deal of what he says about the railway companies and their charges. When you reduce the price of steel from £75 to £5 per ton you are sure to occasion a great increase in the demand for it, and that accounts for the greater variety of purposes for

which steel is being used. Doubtless it would be so with coal. Only for the fact that I happen to know that Mr. Somers is a model employer, I might have thought from what he says in his address about labour, that he meant English people to work 10, 12, or 14 hours because the people in other countries do. I don't think he means that, and I don't think there is any necessity for it. If we can get intelligence into our works we shall not need longer hours.

Alderman G. H. Dunn (Dudley): When the United States have no protective tariff the men will work for lower wages than now, and in consequence they will be able to send goods into this country at a lower cost than we can manufacture. English manufacturers make a great mistake when they agitate for America to take off the protective duties. There is no country in the world which has its mineral resources so highly developed as the States. Their railways are put down on areas where they have to pay nothing at all for the land. Instead of having to pay £50,000 per mile, like some of our lines, many of their railways were put down for the cost of the ballasting only. In one part of his address the President says:—"In 1870, Mr. Forster's Education Bill was passed, when elementary education was made not only universal but compulsory in this country." That is hardly the way to state the position. It certainly was made compulsory, but not universal. One often hears a good deal of complaint about the educational facilities of Dudley, but I know of no town of its size that offers more educational facilities to the working classes than Dudley does. It is true that the people of this town don't attend the technical schools as much as they ought to do; but you must consider that the number of people who are eligible for the classes in places where there are not many technical trades, is very few.

Mr. W. Brooks: If the railway companies would reduce their rates on large contracts, it would be an excellent thing, and if we could take up the matter and persuade the companies to make such reductions, it would be of great advantage to the iron trade of this district. Technical instruction is a vital thing for the rising generation. Having had a good deal to do with youths who have attended science schools, and those who have not, I know the difference between the two. The difference in the value of their labour to their employers and to the country is more than most people are aware of.

The resolution was then put to the meeting by the mover (Mr. Hall) in the following terms:—"That the best thanks of this meeting be given to the President for his excellent address, and that it assures him of the great sympathy with him in his recent bereavement."

The resolution was carried unanimously.

THE PRESIDENT'S REPLY.

THE PRESIDENT: For the very kind terms employed by the speakers with reference to myself, I am deeply grateful. I did not expect that in writing this address I could voice the feelings of everybody. I didn't find fault with the present hours of work, but what I want is that work-people should not ask for any further reduction until foreign countries reduce their hours of labour. I have no wish to increase British hours of labour, but until foreign countries reduce their hours let ours remain the same as now. I know that the provision of technical schools and classes in Dudley is very adequate, and I wish to impress upon the members here to-night that we should by all means in our power get the young people to make use of the advantages which Dudley offers them. If this is done generally we shall soon find that we have better men and better artisans amongst us than our competitors. I am sure I am very much obliged by your kind criticism I should have been very sorry to think it was an address not worth criticising. At the same time, I am sorry I could not devote a little more time to it. I thank you for your very kind sympathy. I can only say it has lightened the burden very much I am much obliged to you for your attendance here to-night, and hope that during this session we shall have some good meetings, and the papers well worth listening to and discussing.

The second Meeting of the Session was held at The Institute, Dudley, on Saturday, the 2nd November, 1901.

THE PRESIDENT (Mr Walter Somers) presided over a large attendance.

The minutes of the previous meeting were read, adopted, and signed.

A letter from the American Ambassador, acknowledging the resolution of condolence and sympathy passed at the previous meeting, was also read, and ordered to be entered on the minutes.

Messrs. John Edward Pugh and Edward Wright were elected members of the Institute.

THE PRESIDENT then introduced Mr. ROBERT BUCHANAN, who read the following paper:—

THE FOUNDRY CUPOLA, AND HOW TO MANAGE IT.

By ROBERT BUCHANAN.

The foundry cupola, considered as a furnace, is unique in simplicity of form. It consists of a vertical cylinder, lined with fire-bricks or other refractory material, having openings, called "tuyeres," by which the blast enters; a door through which the coke, iron, and limestone are charged, called the "charging door;" and a small hole at the bottom by which the molten iron is drawn off, called the "tap hole." There is also a door on the side at bottom through which entrance is made to fettle the cupola and to make repairs when necessary, and through which the kindling is put in at the beginning, and the *debris* is drawn at the end of the cast or melt. This bottom door is made up previous to the blast being put on, so as to be proof against any metal getting through.

That is the cupola in its simplest form, as used in hundreds of foundries to-day.

The modifications of the short, vertical cylinder, with two blast pipes, which have had any permanence are these:—

(1) Heightening the cupola, by increasing the distance between hearth and charging door.

(2) Having a blast belt, and connected with the blast belt double and sometimes triple rows of tuyeres.

(3) Internal modifications of the sections of cupola containing the tuyeres, by which the blast of air reaches the centre of the fuel forming the bed.

In the times before lifts or hoists were in general use founders necessarily had to keep their cupolas sufficiently low, so that pig iron, scrap iron, coke, etc., could be elevated to the charging platform by manual labour. This system obtains in many foundries to-day. These are necessarily compelled to use short cupolas.

The introduction of lifts or hoists made the lengthening of cupolas between hearth and charging door a simple matter, and so the advantages due to such lenthening could be readily obtained. These advantages are principally the utilizing of the heat not directly expended in melting by heating the descending charges of iron about to be melted, and in keeping a cool charging door for the men to work at.

The increase of distance between hearth and charging door brought into effective use double and triple rows of tuyeres, with the better distribution of blast, more rapid combustion, and quicker melting.

Double rows of tuyeres may be used, of course, on cupolas measuring 8ft. to 10ft. between hearth and charging door, but in such the waste heat going up the stack or chimney would be excessive.

Double or triple rows of tuyeres must be accompanied by increased height, so that the heated gases may part with the greater proportion of their heat before finally going up the stack.

If we now consider the modifications in the interior of cupolas, we shall find that almost the only change which has taken place relates to the portion immediately above the hearth and terminating a few inches above the upper tuyeres.

At this point there is an increase of diameter, and this is carried in a straight line to above the charging door. If any taper be given to the cupola lining it should be in favour of an easy descent of the charges. That is, the diameter of the cupola at the charging door should never be greater than what it is further down. Although built straight, a gradual increase of diameter from charging door to melting zone takes place in all cupolas, caused by the abrasion of the solid iron upon the heated brickwork, and by the heat of the melting.

There is a common belief amongst foundrymen that the contraction of a cupola at the tuyeres is primarily intended to reduce the quantity of coke necessary to form the bed for the first charge of iron. That is a very important function, no doubt, and not to be undervalued, but the greatest benefit obtained is that of getting the blast right to the centre of the cupola. This results in a very intense and rapid combustion over the whole area of the circle, and not simply a local combustion in front of each tuyere. In lining such a cupola, and afterwards in fettling it, care has to be taken that the change from the small to the large diameter is made with a gradual slope and not by a sudden change from the one diameter to the other, thus forming a circular shelf on which the descending coke may hang and so leave the space in front of the tuyeres hollow. In such a case the result would be a "bunged up" cupola. This is caused by the slag being cooled by the blast, with the result that it solidifies across just where the reduced diameter begins.

For successful work the slag in all cases must retain its fluidity as it drops past, and away from, the cooling action of the blast.

The reduction of diameter mentioned is really a lengthening of the tuyeres towards the centre of the cupola, and we get an intense combustion, beginning four to six inches above the top tuyeres, if two or more rows of tuyeres be in use, and extending over all the circular area of the cupola.

A double row of tuyeres gives the necessary tuyere area for the entrance of the blast, and will melt more quickly than tuyeres of equal area congregated at one level.

The higher tuyeres supply the necessary oxygen for the combustion of the carbon monoxide generated immediately above the lower tuyeres, the completed combustion taking place in the melting zone.

The melting zone of a 36-inch cupola, with two rows of tuyeres and blast pressure of 8-oz., begins at about six to eight inches above the upper tuyeres, and extends vertically for twenty-four inches and then terminates abruptly.

One row of tuyeres of suitable area will melt perfectly hot iron, but will do it much more slowly than two rows of tuyeres.

Two rows of tuyeres melt hot and fast.

Three rows of tuyeres will also melt hot and fast, but the upper or third row cuts up the lining badly and necessitates a deep bed of coke. Some maintain that no harm is done although these upper tuyeres have no coke in front but blow on to the iron. The idea is that the carbon monoxide which may be escaping from the melting zone, unconsumed, is met by this stream of air and is burned to carbon dioxide, and the economy of complete combustion obtained. It is doubtful if complete combustion in the cupola is wholly economical. On the contrary, a margin or slight excess of free carbon monoxide will ensure that the oxidisation of the iron and the metalloids we value present in the iron, is reduced to the lowest degree possible. If a third upper row of tuyeres is to be used, then the pipes leading to such tuyeres should be of very small diameter—not exceeding one inch and should connect to a tuyere of 2½in. to 3in. diameter so that the air may enter the cupola at reduced pressure and thus minimise the cutting action of the flame at that place. The disuse of a third upper row of tuyeres does not affect the consumption of fuel adversely, retards the melting speed but slightly, and avoids a very rapid destruction of the lining.

The appearance of the flame at the charging door, when melting is being done, is an excellent index as to whether the cupola is being worked to the best advantage. The cupola stack or chimney should be of sufficient area and height to take away all the escaping gases and flame from the charging door, and so help to make more comfortable the charging of the cupola, which, under the best conditions, is always a laborious operation.

The cupola should be high enough between the upper tuyeres and charging door to allow the ascending flame and products of combustion to part with their heat to the descending charges of iron and coke. Unless during the final 25 or 30 minutes, when charging has ceased, the lining of the cupola at the charging door should not be hotter than a black-heat, or, at most, a dark-red heat.

There should not be, as is so often seen, a continuous flaming up through each topmost charge put on. This continuous flaming through is to be avoided as being a waste of heat. It is a combustion which should take place very much further down the cupola, and is indeed only rendered possible by the charges of coke being sufficiently large to stand this waste of heat and yet have enough calorific power left to do the work required in the melting zone. It is a "consummation devoutly to be wished" that the coke would descend, only gently warmed, to within two feet of the melting zone, there to begin to redden up ready for the work of melting, shortly to begin. For coke to get red hot, perhaps eight feet above the melting zone, is gross waste of fuel, heat, and money. In hot weather it also renders the position of the men charging the cupola almost unbearable.

We may also attribute the flaming through the upper charges to deficient blast, or blast badly distributed, and the same result will ensue with a cupola which is too short. There may be flame in the chimney stack immediately above the charging door; in fact, there usually is such a flame, but the heat from it causes little inconvenience. This flame is the burning of the carbon monoxide, probably from the incandescent coke just above the melting zone, and is characterised by being of a bluish-pink colour, the flame clinging to every little projection and ledge in the chimney stack. When the flame in the chimney is of this bluish-pink tinge, the blue predominating, the flame clinging to the chimney wall as mentioned, now and again running down and burning at an opening in the charge in a ragged sort of way, then it is scarcely necessary to look at the metal being drawn from the cupola. Such an appearance at the charging door always betokens that good melting is being done. A flame of a whitish-yellow colour, extending through the charge and up into the chimney, and often out at the top of the chimney, and without the ragged appearance of the proper flame, indicates that too little air is being blown into the cupola. This flame may be seen in a cupola with proper blast any time the cupola-man opens a tuyere to clear away any obstruction there may be in front of the tuyere, and so allows some blast to escape, thus temporarily reducing the blast pressure. This flame is also an indication of scaffolding or other obstruction to the free passage of the blast. When this flame appears, and the blast gauge indicates a rise of pressure, then it is well to see if scaffolding has begun.

The appearances thus roughly indicated are such as apply to a cupola measuring 14 to 15 feet between tuyeres and charging door, and give, as indicated, a good idea of the general conditions obtaining in the cupola at the particular moment.

The total tuyere area to be economically employed is conditioned by the diameter of the cupola, the blast pressure available, and the density of the coke used.

Whatever be the diameter of the cupola, it is desirable to have the blast effective over its whole area. If the diameter be large, then a higher pressure of blast with a reduced area of tuyeres may be used effectively to reach the centre of the cupola; but the coke must be hard and dense to be satisfactory under such conditions. With a softer coke the tuyere area has to be enlarged so that the proper volume of air may enter in a given time. This stream of air being slower moving, and having a larger surface contact as it enters the cupola, has not such an abrasive action on the incandescent coke as the stream from a small tuyere has, but neither has it the penetrative power of the latter.

Should the tuyeres be set for high pressure of blast and dense coke, and coke of low density be delivered by the makers, as will sometimes happen, it is best to blow with less pressure. Melting will be slower, but the cast may be got through, though later than usual. Hard blowing with soft coke results in the bottom part of the cupola in front of the tuyeres being blown hollow, a solid roof of set slag a few inches above the tuyeres, a "stuck" cupola, and a general mess. There is no single thing which can happen in foundry operations which so nearly affects everyone as a "stuck" cupola. It is a serious financial loss to both employer and employed, and raises a grave suspicion of the capacity of the management should it be anything but a rare occurrence. On the other hand, there is room for just a little legitimate pride when one has mastered the varying conditions attaching to cupola melting, and made the cupola a willing slave answering to every call made upon it.

The total tuyere area to be used on a cupola is given by West, a noted American foundryman, as not to be less than one-ninth the area of the cupola. That is a rule which does not err by being too small a proportion. No general rule, however, can be given for all conditions of diameter and height of cupola. pressure of blast, and character of coke used. The most suitable tuyere area for a particular cupola may only be obtained by trial. The suitability of the particular tuyere area adopted is to be judged by the results as a whole, which should embrace as the most important parts, hot, fast, melting with the smallest quantity of fuel.

Cupola shells, unfortunately, have often much too small an opening for the passage of the air from the wind belt into the interior of the cupola. These openings in the inner shell should be amply large. It is easy to lessen the tuyere area if it be thought well to do so, by making the opening in the brickwork less than the opening in the shell. If, however, one wants to blow with a 5in. tuyere, and the opening through the shell is only four inches, there is an unnecessary trouble and expense in making the trial.

The doors on the air-belt opposite the tuyeres should also be ample in size, being not less than six inches in diameter, with a two-inch

opening in the middle of the large door, this opening being covered by a small door conveniently hung, so that the tuyeres may be poked as occasion requires, without having to open the large door, and so allow an unnecessary amount of blast to escape. The small door may also be used as a peep-hole to see that the tuyeres are clean. The glass and mica usually seen on tuyere doors soon break, or get opaque, through the impinging of particles of dust propelled by the blast. The use of the large tuyere doors will be seen when we come to speak of "Scaffolding."

The height which tuyeres should be above the bottom of the cupola is fixed by the weight of tbe castings to be cast in the foundry, and also by a consideration whether a "receiver" or separate hearth is used in which to collect the metal as it is melted, or whether the iron is collected in the well or hearth of the cupola itself. In the case of cupolas having receivers for the reception of the iron as it melts, the lower tuyeres may be only four inches above the bottom. The metal and slag run directly out of the cupola into the receiver as quickly as melted, and so the lower tuyeres may be as low as desired, provided that the channel-way into the receiver be just a little lower.

In cupolas where the metal is collected in the hearth or well of the cupola itself, and that is the way in this country in the great majority of cases, the height of the lower tuyeres, whether double or single rows of tuyeres be used, should be governed by the class and weight of castings being made, and also, to some extent, by the duration of the cast.

We have seen a description of a cupola having no separate hearth, where the tuyeres were said to be only four inches above the bottom. With such a height of tuyeres the melt would be an exceedingly small one, as the accumulated slag would speedily close the tuyeres. We have found that melting with a cupola twenty-four inches in diameter, having tuyeres twenty-four inches above the bottom, slag would sometimes appear at the tuyeres with two cwt. of melted iron in the hearth, 40 cwt. of iron having been melted and no slag run off.

A cupola with tuyeres any less than 12ins. above the bottom is only suited for hand-ladle work, and even at that height, the continuation of the melt will depend on a careful watch being kept on the slag, which should be run off at the slag hole, if there is one. If there is no slag hole, then it may be run off at the tap hole, but that is an unworkmanlike way of doing it. Every cupola should have a slag hole and it should be used.

The reason for placing tuyeres only a short distance above the bottom is, of course, to lessen the amount of coke necessary for the bed. This must extend at least twelve inches above the highest tuyere, whether single, double, or triple rows of tuyeres be used. It is very doubtful

saving to work with tuyeres so low as to be in constant danger of getting them, and the air passages, filled with slag, and perhaps iron. There is also the risk of drawing off the pig iron and scrap in separate strata, some castings getting all pig iron and others all scrap, instead of the well-mixed iron which may be obtained from a hearth of proper depth.

If low tuyeres and a restricted bed of coke be used, then a fair measure of intelligence, skill, and alertness must be displayed at the cupola if satisfactory results are to be obtained.

Blast Pressure.

Iron may be melted as hot with blast at 6oz. of pressure as with 12oz., but speed of melt and economy of time will suffer. The greater the diameter of the cupola the greater will be the loss of combustible gases when using a soft blast. As the diameter increases so should the blast pressure increase,so that it may reach the centre of the cupola. If thereisa blast gauge it should be seen that the cupola-man is shown its use, and that he consults it. Unfortunately there are hundreds of cupolas melting to-day in charge of men who never saw a blast gauge, and would not know what it indicated if they did see it. There should be a blast guage at every fan or blower, and one on every cupola. The blast guage is an excellent tell-tale of how the cupola is working. If the cupola-man observes that the blast guage is registering 5 or 6oz. more than usual, he is not to conclude that the blower has become much more effective than usual, He should take the rise in the guage as a danger signal, and should see if, as is most probably the case, there is a partial scaffolding in the cupola, and at once take steps to clear it.

Scaffolding, and how to avoid it.

Scaffolding is the term used when the charges of coke and iron have ceased following down as the coke and iron previously charged is burned away and melted respectively. When scaffolding occurs in a cupola there is usually a fairly empty space in front of the tuyeres. Over the tuyeres, however, and extending almost, if not quite, across the cupola, is a roof of solidified slag and iron. Scaffolding may be due to deficiency of fluxing material, such as limestone or fluor-spar. Under such conditions the slag formed is pasty and not truly fluid, with the result that when it comes within the action of the blast as it enters the cupola, the slag speedily changes the pasty for the solid condition. Poor coke, having low carbon, high ash, and low density of structure, otherwise a light coke, is a fruitful cause of scaffolding. The low carbon does not give that intensity of heat so desirable. the high ash gives excessive slag, and the lightness of structure allows the coke to be readily disintegrated or blown away by the blast. Faulty contour of cupola lining, possibly in conjunction with the causes just mentioned, may cause, or help to cause, scaffolding. All departures from vertical lines, or where cupola linings are being drawn in at bottom, should be

done very gradually, and anything in the nature of a shelf carefully avoided. Blowing a cupola with too much blast may also cause scaffolding, but that is a comparatively rare cause where good coke is employed.

The way to avoid scaffolding is just the converse of the causes mentioned. Have ample fluxing material, say 56lbs. of limestone per ton of iron melted. If charges are all pig iron, 40lbs of limestone per ton of iron melted is enough, but then, few founders use all pig iron. Use good coke, with carbon as much over 90 per cent. as can be got at a moderate cost. The lessened melting power of a coke of 87 per cent. carbon is very marked as compared with coke with 90 per cent. carbon. It takes 27cwt. of the 87 per cent. coke to supply as many carbon units as is contained in 26cwt. of coke with 90 per cent carbon. Ash usually takes the place of carbon in low carbon cokes, and it is a very poor substitute. The only place where it is as effective is on the weighing machine. If low carbon coke must be used, and scaffolding is to be avoided, then ample fluxing, light charges of iron, and easy blowing are the means to adopt.

If a piece of pig iron or heavy scrap has got down in front of a tuyere, it forms an excellent nucleus for scaffolding to begin. The large door in front of the tuyere provides a means by which some pieces of coal may be placed in the inner end of the tuyere, against the hottest fuel or slag there, so that the coal may begin burning. If the pig iron or scrap (it is usually a piece of pig iron) blocks the way, then it must be pokered back towards the centre of the cupola, so that the coal gets alight. The tuyere is now closed, and the blast allowed to blow the lighted coal. Such a course has usually a magical effect in clearing the tuyere, as the flame from the coal is very hot. A large door to the tuyere allows the coal to be put into the tuyere by the hand. With a small door the coal has to be thrown across the air belt, with the result that about one piece in six gets where it is wanted. If the unmelted pig iron or partial scaffolding cannot be moved back by the steel bar in the hands of the cupola-man, then the tuyere should be closed by means of ganister or other suitable material, and the other tuyeres be made to melt down the obstruction. The blast should be eased while this is being done, and not put on full until, by poking a hole in the tuyere closed with ganister, it is seen the obstruction has gone. The tuyere may now be fully opened, and the blast put full on, and melting proceeds as before.

If several tuyeres have got black, and the obstruction cannot be moved by pokering, nor by adding coal, nor by stopping tuyeres, you may conclude that the cupola is in a "parlous state." In such a contingency shut off the blast at once, as more air is only cooling the cupola, and making it more difficult to get the coke and iron out. The cupola-men may now experience the delights of getting the coke and iron, some of it half melted, out of a "bunged" cupola. Fortunately, it is a very

satisfying kind of pleasure. One experience of the kind perfectly satiates all engaged in it, and there is no longing for a renewal of the joys which always accompany a "bunged" cupola.

Putting extra limestone or other flux on the topmost charge is of use only if the scaffolding is cleared and melting is proceeding; in this case the added limestone as it reaches the melting zone will render the slags being formed there more fluid, and so help to clean down the walls of the cupola. When the cupola is cleared of the unmelted charges there is always a good quantity of slag and iron adhering to the lining of the cupola. If the cupola has to be fettled next morning, the cupola-men with anxious forethought as to how hot it will be, will sometimes, if allowed, throw quantities of water through the charging door on to the hot brickwork and thus ruin the lining. A better plan is to close the charging door for the night, and allow the air to travel the whole length of the cupola from bottom to chimney top. Leaving the charging door open in the expectation that it will let out some of the heat is a mistake, it only spoils the draught to be obtained by the unbroken continuity of cupola and chimney.

It may be useful to compare the relative drawbacks and advantages of cupolas which have solid bottoms, collecting the metal in their own hearth, and those having drop bottoms, and having separate hearths or receivers. Cupolas which have solid bottoms and collect metal in their own hearths are less expensive to erect, less costly in upkeep of lining, etc., and require less fettling daily. The coke has to heat up, say 30cwt. less of brickwork than in the case of a cupola having a receiver, and so has that heat to bestow on melting. A given quantity of coke should thus produce hotter metal at the tap-hole of a self-contained cupola than will be tapped from one having a receiver, and this is undoubtedly the case.

The tuyeres of a self-contained cupola, however, as already pointed out, have to be high enough to allow a body of metal to be collected in the cupola, and this causes the bed of coke to be higher than is necessary in a cupola having a receiver or separate hearth.

Contracting the cupola in the region of the tuyeres so as to get blast penetration also reduces this capacity for holding a quantity of molten iron. In this respect the cupola with a receiver has an advantage. No metal being collected in the cupola the size at bottom may be reduced very considerably, and so the coke used for the bed may be lessened accordingly.

Cupolas having receivers allow a more perfect mixing of iron, as a large quantity may be collected in the receiver with no risk of having trouble with iron or slag getting into tuyeres. This collecting and perfect mixing of the iron is the outstanding advantage of the use of a receiver, and renders possible the drawing in of the cupola as mentioned. It has no

other advantage. Besides, the channelway or connection between cupola and receiver, through which all the iron and slag flow, is a distinctly tender part. A deep groove gets worn in the bottom of the channel each melt. If a crack develops and the metal begins to come through, and in doing so proceeds to cut up the iron casing, it is almost impossible to go on melting.

We have found it best not to run the metal along the main connector brick. By bedding good fire-bricks end to end along the channel, and renewing these as they get worn out, a very much longer service is got from the main brick. Should the metal get between the joints of the bricks it can get no further than the connection or main brick on which they lie. Should the connection brick get cracked, say by a movement of the receiver, and in heating and cooling this is not unusual, then by making one of the fireclay bricks to span the crack, the connection brick may be made to do service until it can be suitably replaced.

To sum up in a few sentences what has been stated, a cupola which collects the metal in its own hearth or bottom will melt metal more economically than one having a receiver or separate hearth, but will require higher personal skill in management to produce well-mixed iron. A cupola having a receiver, takes more fettling to keep in order, is not so economical of fuel, having a larger body of brickwork to heat up, but gives more perfectly mixed iron.

Cupolas with drop bottoms are not very common in this country, most founders preferring those with solid, brick-built bottoms, the coke, slag, etc., being drawn out at the side door at bottom, at the conclusion of the cast. Some who have had drop bottoms to their cupolas have even discarded them and built solid bottoms instead. Drop bottoms are in almost universal use in America.

Drawing a cupola by the side door at bottom, at the conclusion of a cast, as is necessary in cupolas having solid bottoms, is laborious, hot work at the end of a hot day.

With a drop bottom the contents of a cupola may be withdrawn in two minutes without any effort worth mentioning. On the other hand, the drop bottom has to be made up each day, and made up carefully and well. A solid bottom cupola requires practically no making up whatever. When metal happens to make its way down through the folding doors of a drop bottom, as will sometimes happen, there is no necessity to drop the cupola The way to stop the leak is this: turn off the blast, take off the door in front where the kindling is put in and dig away the sand forming the bottom, in the direction where the metal has been coming through. When the spot is reached ram in some good tough sand, and continue ramming until the dripping ceases. Then make up the front door and proceed with the melting. A moulder does the ramming better than anyone else, as he knows exactly the effect he

is producing in making the bottom firm and solid. The operation of stopping the leak and beginning again need take no longer than fifteen minutes.

It is to be observed that on such an occasion the bottom doors are not dropped, the sand being rammed betwixt these doors and the partially-fused sand forming the surface on which the metal has dropped when melted. One material advantage the drop bottom has over the solid bottom is when more iron has been charged into the cupola than is necessary to cast the work then on the moulding floor. When all the iron required has been tapped out, the blast may be turned off and all the unmelted iron and unburnt coke in the cupola dropped, the coke being carefully quenched, to be used again the following day. In such a case when using a cupola with solid bottom the cupola-men almost always melt the iron and pour it on the floor. It has then to be broken up, is accounted as scrap and is charged into the cupola as such. The coke used in melting this excess iron is consumed, of course, and is not again available.

The cupola-man's motive for doing so is not to waste the coke or iron, but is simply that for him, the easiest way to get out of a solid bottom cupola, iron which is already in, is by melting it out.

Charging exactly the quantity of iron required is excellent foundry practice, but having 1cwt. less than is required is very bad practice indeed, and may result in the "pouring short" of an important casting. If there is any doubt of the quantity of metal in the ladle being sufficient for the mould to be cast, and no more is to be had, then do not hesitate to pour the metal into pigs made in the floor. It is the stupidest of proceedings to follow an error in judgment at the cupola, by turning a good mould into a very indifferent pig bed. That is what is done when a mould is poured with too little iron, and is not at all an unknown thing in foundries.

A few hundredweights of iron in the cupola in excess of the probable requirements is thus used as a factor of safety, and, as already pointed out, the drop bottom allows this margin of safety to be obtained at the cost only of picking out the iron and coke from the *debris* of the cupola and elevating it to the cupola platform.

One additional advantage the drop bottom has, is the easy access it gives to the interior of the cupola for fettling purposes. There is thus a clear balance of advantage in favour of the drop bottom as compared with the solid bottom cupola, for ordinary foundry work.

Cupola Management.

By cupola management, we mean the whole conditions brought into effective use, to produce economically, by means of the cupola, the best metal suited for the casting to be made.

Iron may be melted with a very low ratio of coke to iron, and yet, not be economically melted. If the iron is not fluid enough for the particular work to be cast, then a small consumption of coke per ton of iron melted has been waste and not economy.

Cupolas are too often left to be managed by practically unlettered men, to whom "use and wont" is the only safety, and deviation spells disaster. To look to such for an advance in cupola practice, is folly. On the contrary, the best powers which can be brought to bear on the subject may have full play without exhausting the wonders of cupola processes. The advance of our knowledge regarding these is the only way to mastery.

One of the things we hope the future contains, is, that no one shall be put in charge of a foundry who cannot himself, in some considerable degree, supply some of that higher knowledge which fate or providence or whatever you will has denied to these under him. Then we may hope for a permeating of this knowledge down through the several grades of our workpeople, with the resulting advantages which such knowledge would surely give.

An important quality necessary in one who aspires to successful cupola management is a knowledge of the material with which good results are to be obtained. For this purpose he should know the general effect of the several constituents present in pig and scrap iron, the modifications which these undergo during their passage down the cupola, from the solid to the molten condition, and the effect of the constituents upon the general condition of the casting produced.

It is here that the chemist and founder may co-operate towards that desired end. Chemistry may not be an infallible guide nor may it account for some of the unexplained phenomena seen in the manipulation of iron into the finished product, but it has shed, and will certainly still further shed, a light, to guide us with more certain steps along a path too long beset with the stumbling-blocks and pit-falls of ignorance.

Is the fracture of pig iron a guide to its quality? The reply is "Yes" and "No."

Fracture has been, and is now, the only guide which most founders have regarding the quality of the irons they use. However that may be, it is inevitable, we believe, that, be it soon or be it late, judging pig iron by fracture shall give place to the more precise test of analysis.

Physical structure may sometimes differ in irons of similar analysis and discordant results follow tests of these irons, but the broad fact remains that in the very great majority of cases the same physical effects follow the same chemical constitution. If the exact effect on physical structure of all the constituents present in pig iron be not yet definitely ascertained, if ever it be ascertained, yet there exists a fairly full knowledge of the general effect of chemical constitution upon physical

condition. If we cannot have the electric light to dispel the darkness, there is no reason why we should not use a candle.

The chaotic condition of the numbering or grading of pig iron as an index of quality, makes an ironfounder who uses chemical analysis in buying, and mixing, his irons, to feel he has found a footing on firm land, instead of on a bog-land of uncertainties.

Analysis shews the vargaries of the numbering of iron. The No. 1, No. 2, and No. 3 of one maker are not the No 1, No. 2, No. 3 of another maker, and sometimes to help to complicate matters one maker's irons will change numbers and each personate the other. Here is an example of irons sold under the wrong numbers, being from the same furnaces, and evidently numbered by appearance of fracture.

	No. 1 Pig Iron.	*No. 2 Pig Iron.*
Silicon	3·149	3·826
Phosphorus ...	1·042	1·092
Sulphur	0·028	0·025
Manganese... ...	0·480	0·380
Combined Carbon...	0·225	0·157
Graphitic Carbon ...	2·901	3·504

Why should there not be a chemical test for each cast, and sell on that test?

Founders have a right to expect that a pig iron of a given brand and number should have some consistency of character. Take the following six analyses of a No. 3 pig iron of one brand, as delivered at different dates:—

	Nov., 1897.	Oct., 1898.	Feb., 1899.	Mar., 1899.	May, 1899.	May, 1901.	Maximum variation.	
Silicon	3·337	3·359	2·239	2·799	2·893	2·706	Si	1·120%
Phosphorus ...	1·110	0·898	1·581	1·548	1·558	1·636	P.	0·738%
Sulphur	0·016	0·041	0·045	0·032	0·037	0·031	S.	0·029%
Manganese ...	0·410	0·362	0·274	0·280	0·308	0·337	Mn.	0·136%
Combined Carbon	0·581	0·496	0·245	0·026	0·152	0·066	C.C.	0·555%
Graphitic Carbon	3·442	2·462	3·501	2·708	3·250	2·880	Graph. C.	1·039%
Total Carbon ...	4·023	2·958	3·746	2·734	3·402	2·946	Total C.	1·289%

Another brand of pig iron, bought as a "close" No. 3, and at another time as an "open" No. 3, thus clearly indicating it was being sold by fracture, gave the following analyses:—

	"Close" No. 3.	"Close" No. 3.	"Open" No. 3.
Silicon	3·033	2·006	2·613
Phosphorus ...	0·652	0·731	0·795
Sulphur	0·066	0·065	0·044
Manganese ...	0·280	0·490	0·445
Combined Carbon...	0·348	0·402	0·525
Graphitic Carbon ...	3·302	2·550	2·780
Total Carbon ...	3·650	2·952	3·305

Here we find one of the deliveries of "close" No. 3 differs from the other by 1·027 per cent. of silicon, and is inferior to the "open" No. 3 in respect of sulphur alone.

Such differences as have been noticed, and they could be largely supplemented, may be unavoidable in blast furnace practice, but the ironfounder must recognise that such differences exist. These differences can be best indicated by the metallurgical chemist; and by aid of the information thus obtained the manager of the cupola is helped to produce, with a regularity obtainable in no other way, a mixture of iron in which is found the qualities necessary for the work in hand. If he has no definite data, how can he produce definite results?

Coke should also be bought by analysis, supplemented by due attention to density of structure. Ash and sulphur should be as low as can be obtained, and even in coke of good reputation these vary considerably.

Taking ten analyses of coke the results were as follows:—

	Sulphur.	*Ash.*
Lowest percentage ...	0·530	6.520
Highest " ...	1·068	10·300
Average " ...	0·769	8 604

The coke with 1·068 per cent. sulphur caused much trouble by hardening the castings.

Coke with 90 per cent. carbon may be considered satisfactory in this respect. Carbon should not be allowed to drop below 86·5 per cent., as even at this percentage a marked difference in the melting power is noticeable, as may be expected. Coke with 91·78 per cent. of carbon is the highest carbon we have met with.

Limestone used for fluxing should also be analysed, as a small difference in composition may alter considerably the character of the slag either in the molten condition or when hard and adhering to the lining of cupola and ladles.

Analyses of Limestone.

	(1)	(2)
Calcium Carbonate ...	98·02 ...	95·01
Magnesium	1·05 ...	—
Silica	·43 ...	4·16
Alumina	·20 ...	·40
Oxide of Iron	·23 ...	·43
Oxide of Manganese ...	·07 ...	—
	100·00	100·00

The limestone marked (2) formed a slag remarkable for the difficulty with which it could be detached from the walls of the cupola and receiver when chipping down preparatory to fettling for another cast. The limestone marked (1) is superior to the other in respect of the high percentage of calcium carbonate and comparative freedom from silica.

Scrap Iron.

In mixing iron according to the analysis of the several irons to be used, the scrap iron coming from the foundry as "gits," wasters, etc., is readily classified as to its position, being similar in analysis to the castings produced. Bought-in scrap from its miscellaneous character forms the most doubtful part of the whole.

Heavy machinery scrap may be considered as having silicon 1·8 per cent., phosphorus 0·8 per cent, sulphur 0·11 per cent.

Miscellaneous light or medium scrap may be considered as having silicon 2 per cent., phosphorus 1 2 per cent., sulphur 0·11 per cent.

In the sample mixture given, silicon, phosphorus, and sulphur are taken as being the constituents ot greatest importance in the castings designed to be made.

In some classes of work other constituents may rise into prominence, and one or other of these may be relegated to a position of secondary importance.

This sample mixture, by the analytical method, is chosen not because it is particularly accurate, but is given as an exact representation of what may be done in daily work.

Pig Iron.	cwt.	Silicon.	Total Silicon.	Phosphorus	Total Phosphorus	Sulphur.	Total Sulphur.
Holwell No. 3	2	3·546	7·092	1·141	2·282	0·029	0·058
Stanton No. 2	2	3·826	7·652	1·092	2·184	0·025	0·050
Barrow XXX	1	1·959	1·959	0·285	0·285	0·070	0·070
Hematite ...	1	2·250	2·250	0·045	0·045	Trace	Trace
Scrap ...	4	2·000	8·000	1·200	4·800	0·110	0·440
	10		26·953		9·596		0·618

To get the average silicon divide 26·953 by 10 and deduct 0·25, being the average amount of silicon loss, in the course of one melting of iron.

To get the average phosphorus divide 9·596 by 10, but as phosphorus does not lose or gain anything in the course of melting, nothing is added or deducted.

To get the average sulphur divide 0·618 by 10 and add 0·038, being the average gain of sulphur in the course of one melting. The figure 10 represents, of course, the number of cwts making up the charge.

The result, as checked by the analysis, is as follows:—

	Estimate.	Analysis.	Difference.
Silicon	2·445	2·519	0·074
Phosphorus	0·959	0·868	0·091
Sulphur	0·099	0·104	0·005

By making mixtures in this way one can usually get very near the exact constitution of the product so far as a chemist can reveal it.

One could not have the same exactitude mixing irons by fracture. There is also this immense advantage to the founder. He is not tied to the use of any one make of iron but may make his mixtures with confidence, whatever the name or brand, so long as the conbination yields the requisite per centage of each constituent.

The use of test-bars is a valuable adjunct to such a system of mixing. Both test-bar and analysis will be found to have a very vital relationship, of which indeed there is abundant proof, and so requires no further consideration at this time.

Having begun the mixing of iron as shewn, it is continued by the pig-breaker. Where several stacks of one brand of iron are in the yard, these having come in at several different times, will represent very probably several casts at the blast furnace.

Each day's requirements should be drawn from several of these stacks and so a truer average quality of the iron is obtained.

Another good system is to lay one long layer of pig iron from the first truck; on top of that put the pig iron from the next truck and so on. Then begin using at one end and work from top to bottom. Thus the pig iron is getting well mixed before it reaches the cupola, and helps considerably to regulate the quality.

Charging the Cupola.

We shall take it that the bottom of the cupola is in good order, the inside contour of lining free from sudden changes of diameter or projecting knobs of slag, which may hinder the regular descent of the charges of coke and iron as melting proceeds. The first thing to do is to ascertain the depth of bed necessary to begin the melting. It is the upper part of the bed which melts the first charge of iron. The coke in front of the tuyeres does not melt the iron, unless it be indirectly.

The action is as follows. When the blast strikes the coke immediately in front of the tuyeres, carbon dioxide, or carbonic acid, is formed. The carbon dioxide so formed, passing up through the next layer of incandescent coke, is immediately reduced to carbonic oxide, which, combining with the free oxygen of the blast, produces the intense heat of the melting zone and passes up the cupola as carbon dioxide. There is also some unconsumed carbonic oxide which escapes up the cupola, and is to be seen burning in the chimney or stack. The presence of unconsumed carbonic oxide in the cupola is not altogether an evil, as it prevents, in some degree, oxidation of the iron. The melting zone is the section of the cupola where the combustion of the carbonic oxide is practically begun and completed with the production of a most intense heat.

The region of highest temperature, as indicated by the wear of the lining, is at the top of the melting zone. The position and depth of the melting zone is fixed by the quantity and pressure of blast used, but may vary to some extent as tuyere area and cupola diameter vary.

It is a most important fact to remember that no actual melting takes place until the metal reaches the top of the melting zone, no matter how much coke is put on above the zone. Were it piled four feet high, the

coke is simply burned away until the iron gets down to the melting zone, where it at once changes the solid for the liquid state, and so drops to the hearth.

Not any more coal than is actually necessary should be used in kindling, as ordinary coal usually contains more sulphur than is desirable, and tends to harden the first iron melted.

Many cupola-men make the mistake of over-burning the bed before making up the bottom door and beginning charging.

The bed requires to be kindled as high as the tuyeres, and that only, and charging the iron may begin. The pig iron, which has been broken into four pieces, if for a cupola of over 30 inches diameter, or into six or eight pieces for lesser diameters, is weighed and charged into the cupola. It is a good plan to put a thin layer of scrap on the top of the bed to keep the solid pig iron from smashing the upper layer of coke. Then, after the pig iron, the remainder of the scrap is charged and evenly distributed over the cupola. On the scrap is now placed the charge of coke, also evenly distributed. Some limestone, to flux the ash of the coke and the sand adhering to pig iron or foundry scrap, is now added. Some cupola-men, however, do not begin adding limestone until the first charge after the cupola is filled up, but I fail to see any advantage in this.

The charges as stated are continued until the cupola is full to the charging door. It is important that the coke occupies a distinct stratum between the charges of iron, as only by this means is the bed kept level as melting proceeds. Projections inside the cupola may also tilt a part of the charge, and so cause an irregular descent to the melting zone. Level charging, and a level descent of the charges, go a long way towards satisfactory melting. When the cupola has been charged to the charging door, the blast may be put on as soon as is convenient. Some people advocate a period of one or two hours as a proper time to elapse between finishing charging and putting on the blast.

We have found no inconvenience whatever in blowing as soon as charging is finished, if the bed is kindled to the tuyeres, and no cupola should be charged unless it be kindled to the tuyeres. Blowing quickly after charging will give hotter first metal that what is got with a longer interval of time. When the coke is called upon to give up its heat, it should do so rapidly, and with its whole vigour, and should not be employed in "warming the charge," as it is termed.

The quantity of coke put on between the charges should only be sufficient to keep the bed level with the top of the melting zone. When a charge of iron has been melted, and the layer of coke has followed down by reason of the weight of iron and coke on top of it, if the coke be too great in quantity, and more than replaces the coke consumed in melting the iron just liquified, the result is a partial cessation of melting

until the excess coke is burned away, and the iron is down to the top of the melting zone. By the time the charge of iron has melted, the fuel in the melting zone will have sunk a distance which depends on the weight of the charge of iron melted. The charge or layer of coke which follows should just exactly fill the space vacated by the coke used in melting the previous charge. Were the important facts understood, that iron is melted only in the melting zone; that coke intervening between it and the melting zone is simply burned away; that the sinking of the incandescent fuel in the zone wants replacing and no more, then melting would be more rapid and very much more economical than it usually is at present.

It will readily be understood how it is that charges of coke which are too large cause the melting to be slow and hot. Slow because the iron cannot get down quickly enough to the only place where it can be melted, and hot because of the excess of fuel. The excess fuel, for want of something better to do, cuts up the lining usually.

Each cupola may be put upon the best melting conditions only by trial.

To do so, in the morning, before fettling is done, look for the melting zone of the previous day. Measure the distance from top of zone to sill of charging door. Saw a length of wood a foot shorter than the distance found. Charge the coke until the piece of wood, resting one end on the coke, comes just level with the sill of the charging door. The coke has been weighed, of course, and it will be found that it takes more coke each day, as the lining wears, to bring the bed up to the same height as tested by the measuring stick.

A thorough fettling each week brings the cupola back to the original form, and so there is soon established a system of regular height of bed. Do not let the cupola-men depart from weighing the bed and all charges of coke They may profess to know the weight they shovel on, but they don't.

If the melting is hot and slow, that the charge of coke on the top of each charge of iron is too large, will be confirmed by too much flame of a luminous character at the charging door.

Reduce the quantity so charged by, say, 28lbs. each charge, and continue for a day or two charging the same way. If the metal is hot, and probably faster melted, again reduce the coke by another 28lbs. per charge, and so continue until the danger limit is reached. This will be indicated by the metal getting dull at the end of the melting of one charge and hotter at the beginning of the next. This will not go on long, as the bed is now being called upon to contribute more to the melting that what is being replaced by the charges of coke reaching it. The last deduction of coke should now be replaced and so continued.

The metal should now be of a regular heat, quickly and economically melted.

When melting down the last two charges of iron, reduce the blast to half-pressure. It does not retard the melting appreciably, saves the coke remaining in the cupola, and avoids wasting the lining. More linings are wasted in the last 15 minutes' blowing than for hours previously.

The following is the system of charging a 36-inch cupola, two of which, as well as a smaller one on special work, are in use at the Soho Foundry of W. and T. Avery, Ltd., Weighing Machine Manufacturers, Birmingham:—Inside diameter of cupola, 36in., contracted to 19in. at bottom. Height, bottom plate to charging door, 15 feet. Two rows of tuyeres of 78 square inches total area. Melts over 4 tons per hour, and 20½ tons have been melted in it in one afternoon. Each cupola has a separate hearth or receiver for collecting the iron as it is melted. From the receiver the metal is tapped into the ladles.

The system of charging may be best followed by beginning at the bottom and reading up.

Charge 10cwt. Iron Charge 1cwt. Coke	and so on, until after second last charge of iron, when only 56lbs. of coke is put on.
Charge 10cwt. Iron	
Charge 1½cwt. Coke Charge 10cwt. Iron	Cupola full to charging door, when 50cwt. of iron is in
Charge 1½cwt. Coke	
Charge 10cwt. Iron Charge 1½cwt. Coke	Blast pressure 8 to 10 oz.
Charge 10cwt. Iron	
Charge 1½cwt. Coke Charge 10cwt. Iron	24 to 28lb. of limestone put on top of each charge of coke.
Bed 5cwt. Coke ...	

The average expenditure of coke over a period of one month is as follows:—

For light castings	1lb.	of coke	melted	7·87lbs. of iron.
,, heavy ,,	1lb.	,,	,,	10·00lbs. ,,
Average for month	1lb.	,,	,,	8·49lbs. ,,

The light castings are debited with the bed of coke. After the cupola is charged level with the charging door, the coke charged is at rate of 2cwt. per ton of iron charged, excepting the last coke put on, which is only 56lb. between the two last charges of iron.

Metal appears eight minutes after the blast is put on, and is hot enough throughout the melt to run castings sometimes under one-eighth of an inch in thickness, moulded and cast at a distance of 250 feet or thereby from the cupola.

Melting Ratios.

This is a subject which probably interests foundrymen more than any other, and in regard to which there is considerable romancing by cupola makers and some others.

Some of the absurd claims as to economy of fuel, would only be fitted to make one smile did one not know that these questionable statements too often mislead to a serious extent people with capital invested in foundries.

Their acquaintance with melting is not such as enables them to judge of the case, and so they accept these statements as authoritative. Such misleading claims only cause trouble and annoyance for people who have the melting to do, and disappointment for those who employ them.

When absurd claims are made, say of melting 16lbs. of iron with 1lb. of coke, one wonders what was done with the metal when it was melted. Did it run castings? That is the object for which iron is melted. What was the proportion of waster castings? It is as important to know the answer to these questions as to know the proportions of iron and coke. We believe metal may be melted in the ratio stated, but we do not believe the castings of an average foundry can be run with the metal. What then is a good, that is, an economical ratio of coke to iron? It cannot be stated in one word. What is good and economical melting under one set of conditions may be waste under another set of conditions. Condition of cupola, volume of blast, quality of coke and of the iron to be melted, kind of castings to be run, and distance the metal has to be carried, are all important matters affecting the answer.

An economical melting ratio is one which, under the prevailing conditions, shall produce with the smallest quantity of coke, metal suited for the work to be cast.

Can all cupolas as now worked be considered as having economical melting ratios? Investigation would shew, we have no doubt, that the number on which no improvement may be made is a small minority indeed.

Effect of Cupola Melting upon the Iron.

That iron undergoes some changes, other than being melted, in its passage from the charging door of the cupola to the foundry ladle, is known to most founders.

Silicon always gets oxidised to some extent, losing ·20 to ·30 per cent. each time the metal is melted.

Manganese loses on an average ·093 per cent. each time the metal is melted. The smallest loss we have observed is ·056 per cent., and the greatest ·134 per cent.

The manganese in the castings averaged ·259 per cent.

Phosphorus goes through the cupola practically unaltered in quantity. Blast and flux have little effect upon it, and one sometimes wishes they had more. The only phosphorus which passes into the slag seems to be that present in the iron which is oxidised, and goes into the slag taking its phosphorus with it.

Irons containing one per cent. and over of phosphorus have great fluidity and running power, so that thin castings may be run with an iron of this character with great facility. The fluidity and running power of such iron is due to the low melting point of phosphide of iron, which is the condition in which phosphorus is present in iron. This melting point is several hundred degrees of temperature under that of the iron which envelopes it, and through which the phosphide is interspersed. At the moment the iron melts, the phosphide has risen several hundred degrees above its melting point. This fact supplies the reason why phosphoric irons run with such fluidity; the phosphide having to cool down through many degrees of temperature, lower than the "setting" or freezing point of iron free from phosphorus, before reaching its "setting" or freezing point. The cooling action of a mould has thus an effect on low phosphorus iron which it fails to have on phosphoric iron. Iron containing phosphorus is thus easier melted than non-phosphoric iron, because it melts and is fluid at a lower temperature. Iron containing ·20 per cent. of phosphorus we may term a low phosphorus iron. Iron containing one per cent. and over we may term a phosphoric iron.

Sulphur is the source of much trouble to the ironfounder, hardening castings very considerably if ·14 per cent. be present, and at ·15 per cent. the iron is too hard to machine.

Coke, with sulphur averaging 0·769 per cent., increased the sulphur in the castings as follows:—

Minimum	increase	of sulphur	during melting,	0·020	per cent
Maximum	"	"	"	0·079	"
Average	"	"	"	0·038	"

The average is that of twelve meltings.

As sulphur increases in the coke so will it increase in the casting. The importance, therefore, of using coke with little sulphur cannot be too much emphasised.

If the cupola is melting dull iron, a greater proportion of sulphur goes into the iron than when hot melting is being done. The first iron from a cupola, not being so hot, usually, as that melted later, is higher in sulphur, and so such iron is poured into castings with little or no machining to be done on them. If the cupola melts dull all through the cast, then the iron will, from this cause, be hard all through the cast. This absorption of sulphur by dull iron is evidently due to the slag being viscous or pasty, and in such a condition has a feeble combining or

basic effect on the sulphur. Slag has a higher melting point than iron. The iron on melting combines with the sulphur, forming sulphide of iron, at a temperature under that of fluid slag. If hot melting be done, the sulphur passes into the slag in greater proportion, not because the iron is hot, but by reason of the slag being fluid and so intimately comes in contact and combines with the sulphur-bearing ash of the coke. Thus it is that hot melting makes soft castings. Combined carbon and graphitic carbon need not be considered as being specially affected by melting. The respective amounts to be found in the castings are due more to the other constituents present and also to the cooling conditions of the castings rather than to any action which takes place in the cupola. Carbon, as a whole, is reduced in quantity in the course of melting, but an increase of total carbon is not unknown. However, we believe this forms the exception to the rule.

The loss of total carbon in one melting will probably range from ·130 to ·140 per cent.

Cupola Slag

There is a section of cupola practice which has not had the attention it deserves. There is more iron, not visible to the eye, carried to the rubbish heap than most people imagine. So long as cupola-men get a fluid slag, the iron chemically combined with the slag does not concern them, principally for the reason that few of them know there is iron in the slag, unless it be visible. Slags may contain over 10 per cent. of iron. The lowest quantity of iron in any slags we have had analysed being 1·90 per cent,, and the highest 10·10 per cent.

Taking nine analyses of slag, some of which analyses were averages of three to four meltings, and would thus represent about twenty meltings, results were as follows :—

Average of Iron	4·960 per cent.
„ „ Sulphur	0 270 „ „
„ „ Phosphorus	0·049 „ „

Silica averaged 57 to 58 per cent., and was the product of sand adhering to the pig iron and foundry scrap, and also from the lining of the cupola.

Increasing the quantity of limestone charged does not seem to decrease the percentage of iron, nor to increase the sulphur and phosphorus passing into the slag in any appreciable degree.

(1) Lowest Percentage of Iron.		(2) Highest percentage of Iron.		(3) Lowest percentage of Sulphur & Phosphorus		(4) Highest percentage of Lime.	
Iron	1·90	Iron	10·10	Sulphur	0·129	Iron	5·50
Lime	4·23	Lime	6·10	Phosphorus	0·042	Sulphur	0·13
				Lime	0·600	Phosphorus	0·05
						Lime	22·61

Thus with lime at 0·60 per cent. in the slag we have sulphur 0·129 per cent. and phosphorus 0·042 per cent., these three being the lowest of the series.

With lime increased to 22·61 per cent., the sulphur is increased 0·001 per cent., and the phosphorus 0·008 per cent.

These are very small quantities indeed when compared with the effect one might expect with lime increased from 0·60 to 22·61 per cent.

The slag, with 10·10 per cent. loss of iron, had also the greatest amount of phosphorus (0·16 per cent.), showing that the iron in combining with the slag had taken its phosphorus with it.

It has been already stated that when iron is being melted dull, that is coming out of the cupola at what we may term the "red-molten" condition, a greater quantity of sulphur goes into the iron than when hot melting is being done. This we explained as being due to the formation of sulphide of iron at a temperature at which the slag was pasty or only partially fluid. Although slag has been fluid in the cupola, and has taken up the normal quantity of sulphur, if it be allowed to cool in contact with iron it will give up a proportion of sulphur to the iron. Some iron allowed to cool under slag duriug a period of 120 hours had sulphur increased from 0·107 per cent. to 0·153 per cent., an increase of 43 per cent. At the same time combined carbon had decreased from 0·508 to 0·020 per cent.

There is thus a temperature, which, for want of more precise data, we shall call the "red-molten" condition of iron, at which the slag has a lower combining power for sulphur than what iron has. And also, there is a temperature at which, though the slag has already combined with the sulphur, it will pass some of the sulphur into the iron if they be cooled in contact.

Melting hot is thus the means to adopt for best results, both in quality cf iron produced and in fluidity by which the various castings may be run, each at its proper temper. If metal is produced of equal quality and fluidity each day, with a moderate expenditure of fuel, then you may conclude that intelligence and skill are directing the operations of the cupola. If, on the contrary, there is hot metal one day and dull

metal the next, and this is almost always accompanied by an extravagant use of coke, you may conclude that there is some one about who does not know how to work the cupola.

In foundries as in so many other businesses, the great failing, greater even than the want of ordinary education, is the want of the observing eye and the inquiring mind. With these three combined, in the operations which we have endeavoured to describe and to reason out, one may find a source of continual interest, of delightful and profitable study.

If these notes, taken in the course of daily work, are in many respects incomplete, they only show the necessity for further investigation. We are not of those who would speak of the foundry and of foundrymen as less worthy than others of the attention of those competent to improve the one and teach the other. To the engineering world the cupola is as important as the lathe.

Is there any technical school or college so poor as not own a lathe? We believe there is none. Is there a technical school or college in this country which owns a cupola? We believe, not one.

We trust the time is near, when the science of founding, as a branch of engineering, shall be recognised as worthy of the attention which its importance demands, and thus day by day leave guesswork behind, and reach towards an exact science.

At the conclusion of the paper a number of Lantern Slides were shown illustrating various types of cupolas, and explanations were given of their constructive details and their various characteristics.

I. The Herbertz steam-jet cupola, with annular air opening instead of tuyeres.

II. The Greiner and Erpf cupola, having ordinary tuyeres. and in addition, a series of small tuyeres, ascending spirally to admit air for the proper combustion of the gases.

III. The Mackenzie cupola, having an air opening all round the circumference of the lining, instead of the ordinary tuyeres. Melts very rapidly; but melt must be of short duration, as air opening readily gets clogged up by the slag.

IV. The Whiting cupola, having two rows of tuyeres; the first row being placed low down and both rows being adjustable as regards height. The air belt has a fusible plug in it to give warning if iron or slag has got into the belt. There is also a door in the belt by which such slag or iron may be got out. The air enters the belt at a tangent.

V. West's Centre-blast cupola, consisting of a centre blast pipe, with cap; these being protected on the outside by means of fire-clay or other refractory material. Ordinary tuyeres are also used in conjunction with, or independent of, the centre blast. The arrangement is suitable for large cupolas only.

THE DISCUSSION.

Mr. Thomas Hodgkiss: Will Mr. Buchanan please say what iron he used when he got 10·1 per cent. of iron in the slag, and what iron when he got 1·9 per cent.?

Mr. Buchanan: We never melt the same iron two months together. The charges were as shown, viz., 6cwts. of pig to 4cwts. of scrap, and I cannot say exactly what brand of iron it was we were using when we got 1·9 per cent. of iron in the slag. You will notice that the highest percentage of iron in the table is 10·10 per cent. I once read an article in an engineering paper in which it was stated that phosphorus could be reduced in the casting by filling the receiver of the cupola with wood, which I suppose would be changed into charcoal. I filled a similar receiver with clean hard wood and I got no phosphorus into the slag, but a good deal of iron. I did not try that experiment again

Mr. Walter Jones: For some time past I have been seeking information with regard to improvements in cupola practice. The more books I read on the subject the further I seemed to get from any definite result. One recommended a belt, another no belt. One suggests 4 tuyeres; others say 8, 16, or even 20; and one or two American articles recommended that the tuyeres should be put in different positions. Mr. Buchanan, on the other hand, tells us what to do with the plant, and gives his reasons for it. But there is one part as to which I should like some information. Some people say one ton of iron can be melted with 2cwts. of coke, others say 2½cwts., and others 3cwts. In my experience I have found it has averaged from 3 to 5cwts. The latter may be perhaps extremely high; but this again would partly depend on the number of hours the melt continued. On page 35 it is stated that for light castings 1lb. of coke melts 7·87 lbs. of iron; and that for heavy castings 1lb. of coke melts 10lbs of iron. I have heard it said repeatedly that this can be done; but I saw in an American paper some time ago that there is always less coke used in the office than there is in the cupola. I believe that is true, especially with regard to the people who sell cupolas. They forget the bed or they leave out some other important point. I notice on page 35 of the paper that for—

	Cwt. of Coke.	lbs.	lbs. Coke.	lb. Coke.	lbs. of Iron.
The first 1 ton of iron requires	6½	= 2240	÷ 728	= 1	to 3 ,,
,, 2 tons, 3cwt. extra	9½	= 4480	÷ 1074	= 1	to 4·21 ,,
,, 3 ,, 3 ,,	12½	= 6720	÷ 1400	= 1	to 4·8 ,,
,, 4 ,, 3 ,,	15½	= 8960	÷ 1736	= 1	to 5·16 ,,
,, 5 ,, 3 ,,	18½	= 11200	÷ 2072	= 1	to 5·4 ,,
(At 2cwts. per ton.)					
,, 10 ,,	28½	= 22400	÷ 3192	= 1	to 7· ,,

The first	4	tons	requires nearly	4cwts.	coke per	ton of	iron melted.
„	5	„	„	3¾	„	„	„
„	10	„	„	3	„	„	„

In my own practice the coke has varied from 3cwt. to 5cwt. The latter was with a poor quality of coke, and the 3cwt. confirms very nearly the figures given by Mr. Buchanan.

Mr. Buchanan: The quantities of coke used are absolutely correct as stated. We weighed everything, and the accuracy of our work may be judged from the fact that, in a whole year's operations, melting thousands of tons of iron, we were correct in our coke consumption, compared with our purchases, to five tons. As regards Mr. Jones's method of calculating the consumption of coke, it may work out as he says, but it all depends on the amount of melting done after the cupola is charged. If you can go on melting up to twenty tons with 2cwt. of coke to every ton of iron, your proportion is very much lower. I took one month's melt of iron and compared it with the consumption of coke, and the results are as stated. Of course, for obvious reasons I did not state the amount of light and heavy castings made; but if any gentleman is sufficiently interested, I am quite prepared to substantiate anything I have said. The average coke consumption depends largely upon what melting is done after you start melting with 2cwt. of coke per ton of iron charged.

Mr. W. W. Pagett: I believe it is the custom in America to have short melts. They melt every two hours, wh reas we in England go on for four or five hours. If we were to adopt their system, it would, in many of our foundries, involve very costly structural alterations. I think we err too much in restricting our cupola stagings. Rapid work means a great increase of ladles and of means for handling those ladles. Many of us do not possess the plant necessary to advantageously utilise the American system of rapid melting.

Mr. W. H. Richards: From what cupola does Mr. Buchanan get his results?

Mr. Buchanan: From a modified form of the Stewart "Rapid." As I could not see why the gases should come into the receiver for the purpose of going up the pipe connecting the receiver and cupola, I altered the cupola a little. We always found the pipe filled with slag at the mouth, so we took the pipe away and made some other modifications. Taking it altogether it is a good cupola when it is in fair running order, but it is more troublesome than the ordinary cupola.

Mr. W. Kendrick: Is a belt an advantage over separate tuyeres, and a separate pipe to each tuyere from the main?

Mr. Buchanan: I believe so; but I do not quite know. I like the belt. If there are a number of pipes coming out of a main in the

ground they form obstructions round the cupola. The fewer pipes you have on the ground the better, so as to enable you to move freely about your cupola.

Mr. T. CHATWIN: Yes, but you do not get the same blast pressure.

Mr. W. H. RICHARDS: I find that separate pipes are better, and I think you get one sixth more pressure with separate pipes than with a belt. Two mains can be run, one on each side of the cupola, with branches on. This will not be in the way of the cupola men. The distance from the tuyeres to the bottom of the charging door is given as fifteen feet; but my experience is altogether different from that. I think the cupola should be charged from ten to thirteen feet, instead of right up to the door. Now I agree that there is greater wear during the last part of the operation; but I do not think that is caused by the blast. It is caused by the fuel and the metal being removed, and then the lining falls in. I have noticed that scaffolding of the cupola is always followed by the falling in of the lining. If the cupola is charged up to the top, you cannot get a good biting blast, and that means slower melting. There is not a free outlet for the air, and the cupola gets damped, aud this leads to the hanging of the charge over the tuyeres.

Mr. BUCHANAN: I don't think there is anything in that. It is entirely a question of blast pressure and method of charging. If you are using small coke, and, possibly, small scrap, you can get your cupola very dense indeed, and that offers very great resistance to the passage of the blast through the cupola. What I say in the paper with regard to charging is true of the cupola I use, but I do not say it is true of every cupola. Every cupola must be put on its own merits. I have endeavoured to avoid laying down one rule for all cupolas. There is a great deal we do not know about cupolas. In the past the foundry has not had the treatment it deserves, and has been considered beneath some people's notice. The longer I am at the business the less I agree with them. A little of the attention that has been given to other branches of engineering might well be diverted to the foundry, and endeavour made in quarters capable of teaching us all something, so that foundry practice may be put on a higher plane than it has hitherto occupied.

Mr. W. H. RICHARDS: I should like to know whether slightly sloping the tuyeres towards the centre of the cupola, downwards towards the hearth, has been tried. Mr. Buchanan speaks of one of the modifications of the cupola being the height of them. What advantage would he claim from the height of them if he requires to get his charge down as gently as possible to the melting zone?

Mr. BUCHANAN: As regards sloping the tuyeres downwards, I do not believe the air goes down. It may go down to the mouth of the tuyere,

but it then at once begins to ascend. It has the coke in front and every gas in the cupola is ascending. If you want the air at the lower point of the slope you might as well put the back of the tuyeres at that level. The sloping tuyere has the advantage that if the metal is rising and has got into the tuyere, if the man taps his furnace the tuyere will then empty itself into the cupola; but with the horizontal tuyeres the iron will run into the air belt. At the Carnegie Works at Pittsburgh there are cupolas 30ft. between the hearth and the charging door. The advantage of a high cupola is that the ascending gases are robbed of their heat by the descending charges of iron. It is desirable to take the heat from the gases. A month or two ago, to get an idea of the temperature of the gases which were passing the charging door, I put a rod of lead in with a pair of tongs. It took 1¼ minutes before it began to melt. Then I got a stick of solder, and that took ¾ minute before it showed signs of fusion. That showed the temperature of the escaping gases to be very low. It also showed that the heat in the ascending gases had been absorbed by the descending charges of iron.

Mr. T. CHATWIN: Mr. Buchanan is quite right in saying that many makers do not reckon bed-charges. I should like to know how it is that the coal used in kindling the cupola makes the first iron hard, while in America they use as much coal as coke. Then again, Mr. Buchanan recommends the use of scrap. But would that answer unless you waited until the pig-iron had melted?

Mr. BUCHANAN: As to the coal used in kindling hardening the first iron, in America they use anthracite to melt with; but we don't kindle our cupolas with anthracite. I cannot absolutely prove that we get sulphur from the kindling coal, but the probability is that we do. In some coking coals there is as much as 1 per cent. of sulphur. Even if it were only half of 1 per cent. in the coal, it would get into the iron. We cannot compare our kindling coal with the anthracite used in America, for the sulphur in the latter is quite as low as the sulphur we have in our foundry cokes.

Mr. W. H. RICHARDS: Reference has been made to a first charge being hard. That is because the bed is wet. There is always a lot of steam dormant until the blast is put on. Coal put into the tuyeres to clean them hardens the iron, but I don't know why.

THE PRESIDENT: I have very great pleasure in proposing a vote of thanks to Mr. Buchanan. I am sure we have all been very pleased and have gained much information. There is not the least doubt that many of the cupolas are erected by rule of thumb, and that those in charge of them often do not know how much coke they are using. The paper will arouse the enthusiasm of many of our foundry people, and I hope that Mr. Buchanan will give us another paper before long.

Mr. J. COLLEY: I have much pleasure in seconding the vote of thanks.

We have had a most practical paper this evening. Mr. Buchanan has given his reasons very clearly. I have had to do with cupolas now for many years, but I have never heard anyone tackle the subject so well as Mr. Buchanan.

The vote of thanks was carried unanimously.

Mr. BUCHANAN: I am very much obliged to you for your vote. It has been a pleasure to me to prepare the paper. I need not say it has given me a considerable amount of work and anxiety, but at the same time it has been helpful in crystallising in some degree what were previously merely floating ideas in my mind.

The third Meeting of the Session was held at The Institute, Dudley, on Saturday, November 23rd, 1901.

Mr WALTER SOMERS (The President) presided.

The minutes of the previous meeting were read, adopted, and signed.

Messrs. Thomas H. Dudley and Thomas Laurance Rose were elected members of the Institute.

THE PRESIDENT announced that Mr. Ebenezer Parkes, M.P., had expressed his willingness to read a paper some time after Christmas, upon "Foreign Competition." They had probably seen that Mr. Parkes had recently visited America, on behalf of the British Iron Trade. In accepting the invitation to read a paper, Mr. Parkes agreed that the subject of foreign competition was of vital importance to this district.

Mr. WALTER MACFARLANE, F.I.C., then delivered a lecture on "Modern Steelmaking," which was illustrated by about sixty Limelight Views.

MODERN STEELMAKING.

By WALTER MACFARLANE, F.I.C. (Wednesbury).

Mr. Macfarlane (who was cordially received) remarked that if Great Britain was to maintain her place amongst the manufacturing nations of the world we must be able to keep up the large and constantly increasing supply of good steel, and produce it cheaply: if possible more cheaply than our competitors. Steel had become so essential to our existence—not only to enable us to hold our own by sea or land in a naval and military sense, but in a sense which was more important, namely, in the fierce industrial struggle which was being forced upon us by alert competitors. When he told them that in this little island we produced, last year, nearly 5,000,000 tons of steel, they would realise what an enormous demand was being made upon us. It was easy to talk of *millions of tons*, but did they realise what that meant? The question of producing good steel cheaply rested upon five conditions which they must have all at the same time, namely:—

An abundant and convenient supply of suitable and cheap ores.

Reasonable railway rates.

The very best of approved equipment in the works.

Skilful, experienced, and energetic management in the works.

And a loyal co-operation between Masters, Management, and Workmen.

These five conditions being complied with, he thought we might fairly well maintain our own.

The question of the ore supply was a pressing one. Not only had we been raising immense quantities at home, but we had imported from the North of Spain during the last five or six years an average of five million tons per annum. Last year we imported six and a quarter million tons. We had now fairly well exhausted the North of Spain; we were searching and mining along the shores of that country where they touched the Mediterranean, and were prospecting in other parts of the world. It would depend upon the working out of a mechanical problem whether we could avail ourselves largely of immense deposits which undoubtedly existed in Scandinavia. The ores were poor and did not contain very much iron, but the question was whether they could profitably put them through any mechanical operation that would enrich them. Some people had said that they could do it by

magnetic concentration. It was a problem that was pressing for solution and would have to be dealt with very soon.

While showing a series of views, the Lecturer dealt in detail with the arrangements for concentrating iron ores, and many fine views illustrative of blast furnace design and equipment were also shown, comparisons being instituted between our home practice and the equipment and practice at works abroad.

Discussing the subject of installing more machinery at our blast-furnaces, a reminder was given that where production was rapid and wages high—as in the United States—there was a greater inducement to invest in labour-saving appliances. We were not ignorant of the advantages, nor were we indifferent. The new plant at the Askam Works, with arrangements for electrically charging the blast-furnaces, and for collecting, breaking, and delivering the pig iron were described, and views exhibited which appeared to create considerable interest.

With regard to steel, the Lecturer regretted that pressure of time prevented more than a passing notice of that thoroughly English production, crucible cast-steel. A brief sketch of Huntsman, with a portrait of his son (said to have been remarkably like his father), and views of the works, erected about a century ago, and where the manufacture was still carried on on lines laid down by Benjamin Huntsman, were shown.

The next subject dealt with was structural steel. Speaking from a perfectly independent position, the Lecturer declared that very large quantities of mild steel of splendid, uniform, quality were daily sent out from the steel works. He was not sure that the purchasers rightly appreciated the care exercised day by day throughout the working year to ensure that excellent quality and uniformity.

Mild steel was manufactured by methods which had been introduced by Bessemer and by Siemens.

In each of these processes the conversion of pig iron into steel was by oxidation—oxidation from air in the one case; from ferric oxide in the other. Bessemer found his fuel within the pig iron itself; Siemens used producer-gas as fuel in his process.

The decay and downfall of the Bessemer process had been predicted; indeed the fashion had set in of speaking of it somewhat disparagingly. It was a severe and quick process, and did not lend itself to that deliberation at finishing which was a feature of the Siemens process. Much would depend on cost of production. Siemens' costs had come down considerably. But the recent remodelling of the Barrow Hematite Steel Works, by Mr. J. M. While, by which the cost of Bessemer ingots had been reduced by 4s. per ton, showed that there was still a margin in

many works for bringing down Bessemer costs. Then there was the large and increasing output of Bessemer steel in the United States as a significant commentary on the vitality of the Bessemer process.

It would be a long day ere we got beyond the many valuable lessons Bessemer had taught the steel trade. Are we about to introduce *tilting* open-hearth furnaces with open tap holes? Well, the Bessemer Converter was a tilting furnace, with a tap hole constantly open. They would be compelled more and more to use *fluid* metal for steelmaking. Bessemer had taught the trade that lesson too.

The making of Bessemer steel was illustrated by numerous views, showing the various stages in the manufacture. Recent modifications, such as the Tropenas process, were also illustrated, and its suitability for making sound steel castings explained. The chief drawback was the excessive waste of metal.

Siemens-Martin steel was made by charging a reverberatory furnace with pig iron and scrap steel, and, when melted, "feeding" with good hematite ore. The oxygen of the ore helped in burning out the impurities left in the pig iron, and, at the same time, iron was obtained from the ore by reduction.

The fuel used was gas obtained from cheap coal slack, partly burned in vertical shaft producers. The very high temperature necessary for steel smelting was obtained by the adoption of the regenerative system—a system originated be the Rev. Dr. Stirling, of whom it had been said (without malicious intent) "that he was more concerned about saving coals than saving souls."

The regenerative system, as applied by Mr. F. Siemens, was fully illustrated by lantern views, and the modifications introduced by Dick, Batho, and Wellman, were also illustrated.

In directing attention to a photograph of men charging a large Siemens furnace, the Lecturer expressed the opinion that we could not go on always charging these furnaces by hand labour In these days of modern progress it was not likely that furnaces of 80 tons, 100 tons and approaching 200 tons, would go on being charged by human labour He had been told by people, who had been to America, that machinery was already successfully employed for this purpose at some of the works in the States, and that machinery wonld supersede manual labour for this service before long in England also. A view was shown of a Wellman Charging Machine, worked by electricity; the charge being placed in iron boxes set upon trucks, and a long arm conveying the boxes right into the furnace, turning them over, and thus emptying their contents into the furnace. A view of the charging boxes was shown, and also another view of a Wellman Charging Machine at the Parkgate Works, Yorkshire. The next view was that of a Tomkins Machine for charging steel furnaces at work in Cleveland, and a note from the

inventor intimated that it had worked very satisfactorily. This was operated by an endless belt system, the pig iron being raised to a height and then sent down a shoot into the furnaces. Questions had been asked as to whether the bottom of a furnace would stand knocking about by a charge being delivered into it in this manner; but as a matter of fact it had been found that furnaces *did* stand it. The next view gave a section through a modern steelworks, showing a tilting furnace and charging machine. The furnace was tilted by hydraulic power, and it could be tilted in such a way that at the finish molten steel could be poured out like water from a kettle. The next view showed a tilting furnace with two rams for working it. So far as the Lecturer knew, the first tilting furnace was designed by a general manager well known in the Midlands.

Continuing the description of methods of discharging the metal from a tilting furnace, views were shown of a Swedish Bessemer Converter, with Carpersson's Ladle attached, and a companion picture of a modern tilting open-hearth furnace with ladle attachment showed how like these were, in arrangement, to each other. Pouring through a forehearth was also illustrated, the Lecturer remarking that this device appeared to be derived from the American system of copper-smelting. In the American copper smelting forehearth, the slag was allowed to settle from the "Matte" produced, and it was a great comfort to those in charge of the American Water-jacketed Furnaces. Whether it would prove such a blessing to the steel smelters would probably be proved in a short time, as the Hamilton Steel and Iron Company, Canada, had adopted the arrangement at some of their furnaces. Views of forehearths attached to copper-smelting furnaces were shown, as were also views of the Hamilton Co.'s furnaces with forehearths. This was part of their new steel plant, and the Lecturer remarked that the town of Hamilton had been termed the Birmingham of Canada. To him (he added) it seemed that Canada was to be the great steel-producing country of the future.

Turning the attention of the audience to the important subject of the use of fluid metal (instead of charging cold materials) for steelmaking, the Lecturer observed that it was difficult to understand why those British ironmasters who had both blastfurnaces and steel-smelting furnaces in their works, had been so slow in taking this interesting and profitable matter up. It was well known that, owing to iron going into the slag in the steel smelting furnace, they did not get in the steel ingots which they produced a weight equal to that of the pig iron and scrap charged; to say nothing of the weight of iron in the ore used for feeding.

During the melting down of pig iron, silicon is oxidised without doing the chemical work which it is capable of. But if fluid metal is worked with ore, the benefit of the chemical power of the silicon is obtained.

Instead of the percentage being under the mark, it has been proved to be possible to get 103 per cent. by using fluid metal, while by one of the newer methods 106 per cent. is regularly obtained, *i.e.*, not taking into account the iron in the ore which is used.

We were accustomed to cast our pig iron in sand, but it would, from the chemical point of view, be hard to conceive a substance less suitable. Sand clung to the pig iron and iron was wasted in fluxing it off. Moreover, we were so used to pig iron cooling down quickly in the sand beds, that there was a certain amount of diffidence in dealing with it in any other manner. But we had found out that if molten metal is kept in cube form it was possible to keep it fluid for a long time, and advantage had been taken of this circumstance, with satisfactory results. A picture of a 300-ton metal mixer was shown; the utility of the mixer being that it is possible to take the product of three or four blast furnaces, and, by running the metals into the mixer, a more uniform metal for steelmaking could be supplied

In the course of subsequent remarks the Lecturer expressed the opinion that the rival processes of the future would be the "Bertrand-Thiel," and the "Talbot," with possibly the "Monell." Plant was being put down at various works in connection with both the former methods. The Bertrand-Thiel process was on the principle of tapping off the slag very early. In washing clothes it was usual to get the rough dirt off in one water and to finish in clean water, and it was the same with the Bertrand-Thiel process, in which the partly-purified metal was transferred from one furnace to another (the slag being separated during the transit) in order to finish off. Various modifications of this process were illustrated.

In the Talbot process (which was originated by Mr. Benjamin Talbot, a native of this district), it was customary to charge, say 100 tons of materials into a tilting furnace, work off the charge with ore, as in the ordinary Siemens process, and tap off, when ready, 25 tons of steel, meanwhile retaining in the furnace the remainder of the steel and all the slag. Ore is then charged in and soon becomes melted. 25 tons of molten pig iron are then run in, and a rapid reaction takes place, with evolution of gas, which is burned in the furnace. A portion of the slag is then poured off and the metal is worked down with additions of ore and limestone. When more steel is ready it is tapped off and finished. A fresh charge of ore is put in, followed by fluid metal, and so the process goes on continuously throughout the week, the furnace being kept well filled and hot all the while. The slag is seldom allowed to come in contact with the bottom or banks of the furnace.

The Lecturer next dealt with improved methods of conveying molten metal from one stage of any manufacturing process to another. Why, he asked, should we take metal from the blast furnace in mounted ladles drawn by locomotives to a mixer, and then from the mixer to another

part of the works by a locomotive? In a new works, why not put a blast furnace up at a certain height above the open-hearth furnace and above the mixers? The metal might run down a spout from the furnace into the mixer or into the steel furnace These ingenious ideas were greeted by the audience with applause.

The points next dealt with were the elimination of sulphur and of phosphorus during steelmaking. A portrait was shown of Mr. Ernest H. Saniter, whose process is working successfully to-day in making good steel from pig iron produced from Cleveland ore. The portrait of Mr. G. J. Snelus, to whom the Lecturer referred as "The first one who really dephosphorised in a basic-lined vessel," was also shown, and the importance of the Basic process discussed.

Touching on the life of Sidney Gilchrist Thomas (whose portrait was also shown), the result of his work was referred to as forming another instance of a man outside of the iron trade helping that trade. The same could with truth be said of James Beaumont Neilson, of Bessemer, and of Siemens, whose portraits had been shown earlier that evening. Young Thomas was a clerk in a London Police Court; but he studied the phosphorus question, and by his great energy and perseverance he brought the matter to a practical issue by pushing the Thomas-Gilchrist system; a system which has made available for steelmaking many ores which otherwise would not have been suitable. Among other views shown were several of steel bridges built in record times. Upon this matter the Lecturer said that recently in Wednesbury they had beaten the record and left the Americans behind. At the beginning of September last, the Patent Shaft and Axletree Company, of Wednesbury, received an enquiry from the representatives of an American Railway Company asking if they could design, and supply quickly, bridgework and steel trestles to span two viaducts in South America. The Patent Shaft Company undertook to design and ship the whole of the work in five weeks. The order was received on September 12th, but the location plans, showing the nature of the viaduct, were not supplied until the 16th of September. The first viaduct consisted of seven spans of 40ft. each, and one span of 30ft., along with five trestles of various lengths from 54ft. high to 21ft. high. These viaducts were designed to carry locomotives 78 tons weight. The spans and trestles were made and shipped by the 9th of October. The second viaduct consisted of two spans of 185ft. each, and one large trestle 90ft. high by 46ft. wide. This viaduct complete would have been shipped at the same time but for considerable alterations required previous to completion. The second viaduct had to be re-designed, and therefore delayed the shipment. It was now practically complete, and would be shipped the first week in December. The chairman of the railway company was an American.

THE PRESIDENT: In moving a vote of thanks to Mr. Macfarlane for his very interesting lecture, I can only say that we should thank him most heartily. There is no doubt that the lecture has been a very instructive one, and that we shall all benefit by it.

Mr. H. PARRY: I have very great pleasure in seconding the vote of thanks. Mr. Macfarlane is to be congratulated on having dealt with a lengthy and difficult subject in so lucid and instructive a manner. It is, indeed, useful to have brought before us a systematic lecture of this kind, describing the whole course of iron and steel manufacture, because there are members of the Institute engaged in various branches of the trade who have neither time nor opportunity to make themselves acquainted with details of other branches, and such will, no doubt, appreciate the review which Mr. Macfarlane has given us, accompanied, as it has been, by graphic pictorial representation. A lecture of this kind will dispel many popular impressions, such as might arise, for instance, from reading a paragraph I saw in a paper describing the equipment of a blast furnace, where the reader was gravely assured that water was led into the furnace by the tuyeres! If the stream of water was of the volume mentioned by Mr. Macfarlane as being used at Askham Furnaces, I leave the result to your imagination.

Mr. MACFARLANE: I accept your vote of thanks with very great pleasure. It was with some little diffidence that I submitted a proposal to introduce a lecture like this to such an Institute, because I knew perfectly well it had within its own membership many who were quite conversant with these details. At the same time, I recognised the fact that the very existence of such a society showed that there was something more yet to be learnt. Then again, I think you are not accustomed to such elementary fare as I have given you to-night. But it is sometimes very useful to be put on a plain diet, if only for one meal. The new furnaces and machines which had been brought before them must inevitably work a revolution in the methods of steelmaking at home. As to the Askham Furnaces referred to by Mr. Parry in his remarks, they use a tremendous amount of water. The one I saw was like a waterfall. At these works they have pumping accommodation for 2½ million gallons in 24 hours.

This concluded the proceedings.

The fourth Meeting of the Session was held at The Institute, Dudley, on Saturday, the 14th December, 1901.

The President (Mr. W. Somers) presided.

The minutes of the previous meeting were read, adopted, and signed.

Messrs. T. R. Knowles, William Somers, Percival Mountford, Horatio Booth, John Keeling, Philip Robinson, Daniel Meese, and Harold Piper were elected members of the Institute.

The President then introduced Mr. David Flather (Sheffield), who read the following paper:—

CRUCIBLE STEEL; ITS MANUFACTURE AND TREATMENT.

By DAVID FLATHER.

Any attempt to give, within the narrow limits of a single paper, the history, manufacture, and uses of Crucible Steel, would indeed be fore-doomed to failure, and I therefore propose, very briefly to touch on the historical side, leaving the main portion of our time to a consideration of the actual process of Crucible Steel manufacture, its uses and its treatment by the consumer.

DEFINITION.

By the word "Steel" we understand a compound or alloy of iron with other elements. Such compounds we may divide into two classes, viz., Carbon Steel and alloy or metal steels. The former being compounds of iron with carbon, and the latter, of iron with other elements or metals.

Carbon Steel.

Iron from its first crude state as reduced from the ore has such intimate connection, and has so great an affinity for carbon, that it very rarely is found to be without at least a trace of that element The exact relation between iron and carbon existing in the many forms of steel, is by no means an ascertained fact, and for our present purpose it is not perhaps necessary to enquire. The quantity of carbon which can exist in combination with iron ranges from the smallest traces up to 5 per cent. or even 10—12 per cent. when in the presence of chromium or manganese; but all commercial steels contain from ·1 to 3 per cent., and within these limits are to be found every variety of Carbon Steel in ordinary use.

Metal Steels.

Iron unites also with many other elements. The chief of these are tungsten, chromium, manganese, nickel, and molybdenum, all of which produce steels of varying character, governed not only by the metal employed. but also by the quantity of it in the alloy.

Impurities.

At this point it is well to remember, that in addition to the special element united with the iron, all steels contain, at the least, traces of

other elements and which, only in a greater or less degree, affect the properties of the steel, and in most cases do so to its detriment.

These impurities are principally sulphur, silicon, phosphorus, and manganese. Copper, also, is often blamed for spoiling steel, but there is so much conflicting opinion on this question, that one cannot speak with any degree of certainty.

METHODS OF STEEL MANUFACTURE.

There are four principal processes by which steel is produced commercially :—

A The Cementation Process.
B The Crucible ,,
C The Bessemer ,,
D The Open Hearth ,,

Although the subject of my paper is Crucible Steel, yet the Cementation Process is so very intimately associated with it, that it will, I think, be useful first, briefly to consider the question of Steel Manufacture by Converting or Cementation.

Cementation Process.

In converting iron into steel by this process, advantage is taken of the great affinity of carbon and iron. So strong is this affinity that it is not necessary for the iron to be melted, the carbon being absorbed at a full red heat. This process requires a furnace of special form, in which are two chambers capable of being rendered air tight and of being raised to a bright red heat. For sake of economy of fuel these chambers are so arranged that the fire hole is immediately beneath each chamber and the products of combustion by proper flues circulate all round them. Around the whole is built a chimney, wide at the base, gradually reducing, until about fifty feet from the ground it finishes with an opening of the same dimensions as an ordinary stack of that height, and in general outline it has much the appearance of a malt-kiln. Into the chambers, or "pots" as they are called, the iron, in the form of rolled flat or square bars, is carefully packed in layers alternating with layers of small charcoal until the pots are filled. The charge is then covered in and made perfectly air tight by means of clay. Fire is then put in and the furnace gradually heated until it attains a bright yellow heat (about 1150° centigrade), and is maintained at that heat for a period of time proportionate to the quantity of the charge and the temper of the steel required. The average time is, for a "mild heat" eight days, "medium heat" nine and a half days, and a "hard heat" eleven days. At the end of this time the furnace is allowed to cool down naturally before being opened, and the charge withdrawn. On examining the bars it is seen that a marked change has taken place in their appearance and structure. When put into the furnace, they were of the usual fibrous nature of wrought-iron and having a uniformly

smooth surface, but now they will have become coarsely crystalline, and so brittle that a bar thrown to the ground will break into many pieces, while the surface is covered with blebs or blisters. Hence this steel is usually called "Blister Steel." These bars, on being re-heated and forged or rolled, become of much greater strength than the original iron, and also of much greater hardness. The amount of carbon which can be combined with iron in this manner ranges from ·5 to 1·5 per cent. When Blister Steel is re-heated and rolled or hammered, it is known as "Bar Steel." "Single Shear Steel" is produced by welding together several bars of Blister Steel. "Double Shear Steel" is made by welding together bars of Single Shear Steel. This method of making steel is, as you are doubtless aware, a very ancient one, and as compared with more modern inventions, has a very considerable history attached to it.

The quantity and the quality of the steel made by cementation was, for long years, quite sufficient to meet the demand, but as the requirements of engineers and inventors increased, greater need was felt for steel of more varied hardness and more regular character than could be produced by th·s process.

The Crucible Steel Process.

Like most world-conquering discoveries, the crucible steel process owed its origin to necessity—the great mother of invention. Benjamin Huntsman, born in the year 1704, was the inventor of this method of making steel. In the pursuit of his trade as a clockmaker, he experienced much difficulty in obtaining steel of sufficiently regular quality and temper for the purpose of making his clock springs. The steel then at his disposal was made by cementation, either at Newcastle or was imported direct from Sweden. Doubtless, many had felt the need of a better class of steel for this and similar purposes, but Huntsman was the first who deliberately set himself to find out a remedy. Knowing by experience that the chief fault of the cement steel was its irregularity he conceived the idea of melting it and casting it into an ingot—thus to obtain a regular admixture of all its particles. His first, and greatest difficulty, was to obtain a material for his crucibles sufficiently refractory to withstand the great heat necessary to the perfect melting of the steel. After many failures he was at last successful. He had designed a furnace capable of producing the necessary heat, and so perfect was the construction of this furnace that it has remained practically unaltered to this day. Another difficulty, and a very serious one, was to find out a proper flux. In this he also succeeded, and at last his long and patient striving was rewarded when he found that he was able to melt his blister steel and produce ingots perfectly regular in temper and free from most of the faults of the old steel. For some time his process was kept secret, but by an act of treachery it gradually became known, and was practised by a growing number of firms. In spite of this, I am glad

to say that the steel business founded by Benjamin Huntsman still flourishes and produces steel, the equal, at least, to that made by any other firm. The great object, then, of the Crucible Process is, in the first case, to obtain steel of regular and uniform composition, and secondly to allow of a greater range of hardness in the character of the steels produced.

The actual process as practised to-day is worked on the same lines as those of the original inventor.

The Furnace.

The melting furnace consists of a row of holes in the ground. They are of oval section, and ten or twelve holes are ranged in each set, the flues from which join into one long low stack. The holes are about 6ft. deep, and about 2ft 6in. by 2ft. in section, and are sufficiently wide to receive two of the pots or crucibles. The fuel employed is a specially burnt hard coke, the combustion of which is aided by means of a natural draught. The tops of the holes are level with the ground line, and each hole is covered by a loose firebrick framed with iron. They derive their supply of air from a huge cellar so constructed as to offer the least resistance to the air current, which, rising through the fire bars and the fuel, raises the furnace and its contents to the necessary high temperature. The draught, and therefore the temperature, is regulated in a rather primitive though effectual manner by introducing a loose firebrick into the passage leading from the furnace into the flue, and it is remarkable what nicety of adjustment can be obtained by means of this firebrick; by pushing the brick back or forward, placing it on edge or on its side, the draught can be regulated with as much certainty as could be done by the most ingenious valve or damper.

It will be clear that in order to withstand the extreme heat requisite, both the crucible and the furnace lining must be of very refractory materials; for the latter a very fine gannister is found in the neighbourhood of Sheffield, and the crucibles are made from mixtures of Derby, Stannington, Stourbridge, and sometimes of China clay. Both the re-lining of the melting holes and also the crucibles are made by the steel manufacturer's workmen. Each firm has its own idea of the best proportions, but I have no doubt they are very nearly all alike. Much of the success of the crucible depends first on the perfect admixture and kneading of the clay, and secondly on the proper drying and annealing of the crucibles.

Melting.

Having described the construction of the furnace, we may now proceed to consider the actual process of steel melting. The night before starting the furnaces a complete set of pots is taken from the drying shelves and placed in the annealing furnace and raised to a full red heat. The material for the charges

must also be weighed out and placed in scoops or baskets ready for the first round. This material, of course, varies according to the requirements. Usually a certain proportion of Blister steel is used containing perhaps $1\frac{1}{4}$ per cent. carbon, together with sufficient bar iron to reduce the average of carbon to the required amount. To the quantity required for each pot must be weighed off a sufficient quantity of fluxing material. On starting work for the day, the furnaces are lighted, first with coal and then, after putting in the crucibles, which are covered by their lids, the hole is filled with coke and the draught urged until a full white heat is obtained. The hole is then uncovered, the pot lids are moved to one side, and a wrought-iron funnel is lowered into the mouth of each pot in turn and the charge of Blister steel, &c., carefully placed into the crucible. The lids are re-placed, the furnaces filled up with coke, and the covers replaced. From this point the operation depends entirely on the skill of the melter, who must go round all the holes regularly and watch the process of melting, now urging, now holding back the heat, and so working the holes that the charges shall all be ready in their turn for drawing and casting. The operation of melting may occupy from three to four hours, and during this time much has to be done in preparing for the next round. As a rule, three rounds or heats are got out of each furnace in a day, While the first round is being melted the charges for the second round must be weighed up, also the ingot moulds must be prepared to receive the melting charges. As the steel and the fluxes used in the process react, to a considerable amount, on the crucible in such a manner as to weaken it at the point at which is the level of the molten steel, it is necessary that this level should be lowered at each successive heating. Thus, if 60lbs. of steel be melted in the first round, about 54lbs. only is taken at the second round, and 48lbs. at the third, and after working three rounds the pots are destroyed as being unfit for further use. The steel is not ready for casting until it has been in a molten state for some considerable time, or until, as the expression used by melters says "it is killed." Steel which has not been killed teems "fiery," that is to say, it gives off a profusion of little sparks and appears to boil in the pot, while the ingot when cold will be full of honeycombs. If the steel be too hot it will also show the same fault, while if it be kept in the fire too long it will be very rotten and brittle. Should a piece of coke fall into the crucible it will result in the steel being spoilt by the sulphur present in the coke.

When the melter judges the steel to be ready for casting or "teeming" as we say, each pot in turn is seized by a pair of tongs and pulled up to the floor level and lifted alongside the trough in which the ingot moulds are placed. The lid is removed and the crucible gripped about the middle by another pair of tongs On the surface of the steel floats the flux, and this is rapidly skimmed off. The crucible is then lifted (by hand, of course) and its contents carefully poured into the ingot mould.

This, as you will understand, is a very delicate and difficult operation, and only the most reliable men can be employed for the purpose.

As each crucible is emptied of its contents the lid is replaced and the crucible returned quickly to the furnace and covered with coke until once more it reaches the proper heat to receive the next charge.

The raw material used in the manufacture of crucible steel being blister steel and bar iron mixed in varying proportions according as the composition of the ultimate result may require, and being melted together in such comparatively small quantities, it will readily be seen that great regularity of composition can be obtained by this process, and also, that a steel ranging from say ·25 per cent. carbon to 1·5 per cent., or even higher may be produced.

Classification.

Before proceeding to consider the products of this process further, it will be well to define and consider briefly the two principal heads under which the nature of all steels must be classed. These are distinguished by the terms "Quality" and "Temper." In spite of the advances in metallurgical chemistry, and our accurate knowledge of the composition of all kinds of steel, the old definitions and descriptive terms are still used in connection with crucible steel. And, as a matter of fact, it is quite necessary that it should be so, for crucible steel cannot be judged by the same standard as other and commoner steel. Impurities seem not to have the same effect, the carbon contents are not the same in their action, and so, as I have said, it is better that at least for the present we should continue in the old ways. A very frequent cause of trouble to steel users and therefore to steel makers, is the result of confusion between the terms "Quality" and "Temper." Often does it happen that steel is said to be "too good" or "not good enough" for a certain purpose, when, as a fact, it is either too hard temper or too soft for the work required. In my own work I make use of a third term "Condition," to indicate a state which is due neither to quality nor to temper. A steel may be of very good quality and of exactly the right temper, and yet, owing to its physical condition or faults, such, for example, as seams, cracks, blow holes, want of annealing, etc., be quite unfit for the work it is designed to do.

Quality.

The impurities which affect the quality of steel, and their individual and combined action, are doubtless well known to you, and it will not, therefore, be necessary to go beyond a simple enumeration of those most common, viz., silicon, sulphur, phosphorus, and manganese. But at the same time it is well to state that the detrimental effect of these impurities is not always in the same proportion in Crucible as in Bessemer or Open-Hearth Steels. I have known several cases where analysis has disclosed the presence of an almost abnormal quantity of

one or other of the well known impurities, while the actual working of the steel would not have lead one to suspect its presence in anything beyond the usual "traces."

Of course the actual quality of the steel is decided by the quality of the material used in its manufacture. Blister steel, made from Swedish charcoal iron, is made in many grades of varying purity, and on the proper selection of this material and the bar iron depends the quality of the steel, subject, of course. to its being properly melted.

Temper.

The temper of Crucible Steel is usually described by means of certain words taken from the kind of tools, &c., into which it may be made. Thus you have "Saw temper," "Spindle temper," &c. In percentage of carbon it ranges from about ·25 per cent. up to nearly 3 per cent.

It is, I think, generally known, that the same percentage of carbon has not the same effect in Crucible Steel as it would have in steels made by the other processes. Thus a Crucible Steel having ·80—·85 per cent. carbon will have about the same temper as English Bessemer steel of ·60 per cent.— 65 per cent. carbon, while a Swedish Bessemer would require to have about ·70 per cent. carbon to reach the same temper.

The terms in general use descriptive of these tempers, together with their approximate percentage of carbon are as follows :—

Razor temper	=	1·50	per cent.	carbon.
Saw File temper	=	1·35	,,	,,
Turning Tool temper	=	1·25	,,	,,
Large Turning tool temper	=	1·15	,,	,,
Chisel temper	=	1·00	,,	,,
Sate ,,	=	·85	,,	,,
Die ,,	=	·70	,,	,,

There are, of course, many other and intermediate tempers used, and the above list must not lead anyone to think that each temper can only be used for the one purpose Thus razor temper is used for roll tools, saw file temper for fine drills, and large turning tool temper is used for circular cutters.

Condition.

This is a term which should, I feel, be used in connection with all classes of steel, and is one which should receive more systematic attention than it usually does. It is as much an indication of fitness as are the terms, quality, and temper, and if properly carried out the term "Condition," would give the physical history of every lot of steel from the ingot to the finished article.

In following the Crucible Steel ingot through the processes of its manufacture into its final form, we shall have to touch upon most of those points which tend to make or to mar its condition. It will be

sufficient, therefore, to enumerate the necessary properties and the possible faults. "Perfect condition" should mean that the steel is uniform in composition, homogeneous in structure and of smooth and regular surface.

The mechanical faults which are to be avoided are pipes, laps, seams, honeycombs, rokes, crushes, and the large crystallization due to overheating. One of the greatest evils found in other steels, is absent in the case of Crucible steel. I mean the faults due to segregation, or the separating out of the carbon, or the impurities during the cooling of the ingot, in such a manner as to cause great irregularity in composition and strength. As you are aware, the larger the ingot the greater the risk there is of segregation. In Crucible Steel, however, owing to the much smaller size of the ingots, the steel very quickly passes from the molten, through the dangerous plastic state and solidifies; thus it is almost impossible for an ordinary sized ingot to become faulty through segregation. With this exception, Crucible Steel is, if possible, more liable to mechanical faults than steel made by any other commercial process, owing to the small body of the metal to be treated and the consequently reduced chances of eliminating, by mechanical work, such of the faults as could otherwise be removed or neutralised.

TREATMENT OF THE INGOT.

Having described the process by which Crucible Steel is made, we may, with advantage follow it through the course of its manufacture into the finished bar, and onward so far as possible and see how it is, or ought to be, treated by the consumer. By so doing we may learn how faults arise and how they may be avoided.

The Ingot.

When the steel is properly melted, it is poured into a metal mould, which has been previously coated with soot to prevent the steel adhering to the mould. To pour a stream of melted steel, by hand, down an ingot mould, three inches square, is by no means an easy matter, especially when we remember that if once the stream touches the sides of the mould a strip of the common iron with its impurities will be melted off, and its admixture with the steel—even if it does not entirely spoil the steel—will at least degrade its quality. The ingot mould, I have said, may be three inches square and, as a rule, this is about the average size in general use, but I have here a piece broken from an ingot, of a half-round section, about 1½in. by 1in., that was cast in this way. When you remember that the man who has such work to do, has, within two feet of his hands, a white-hot crucible, which, with its contents, will generally weigh about 70lbs.; that he has to pour the steel down such a small opening, without splashing and without hesitation, that he must not touch the sides of the mould, but must pour in a gentle stream till the mould is full, and must keep on filling

mould after mould until his crucible is empty, and that he will, in the space of about twenty minutes, lift and pour from 10 to 15 cwt. of steel in this manner, I think you will agree that a steel melter's work is not by any means easy.

One of the chief faults which occur in the ingot is that of "piping." A pipe is a more or less deep hollow at the top end of the ingot, and is due to the contraction caused on cooling. In steel under ·85 per cent. carbon the pipe is rarely of any serious amount; but beyond that, and especially above 1 per cent. carbon, a very large percentage of waste results from this trouble. A skilful "teemer" can to some extent prevent piping, but it is never entirely overcome.

When the ingot has solidified it is removed from the mould and allowed to cool.

"*Ending.*"

The next operation is that known as "Ending," which consists in breaking off the ends of the ingots while cold. This is done for two reasons, first to remove all trace of piping and all blow holes that may have risen to the top; and secondly that the head melter may judge of the exact temper of the steel, for it is just as necessary for the maker of a 50lb. ingot to verify his results, as it is for the maker of Bessemer steel to take test pieces and have them analysed or tested mechanically. It is remarkable to note with what accuracy the practised eye of the melter can judge the temper of the steel by the appearance of the fracture. It is no exaggeration to say that they can judge certainly to within one tenth per cent. of actual carbon, and at the same time are able to state the exact nature of the steel as regards its general impurities. Should the first piece broken from the ingot end not show clear of pipes or blow holes, more must be taken off until a clean and continuous fracture is obtained.

Wash Welding.

The ingot having been "ended," it is next taken to the forge to be wash-welded. This is to say, the steel ingot is heated to as high a temperature as its nature will permit, and at the same time its surface is covered with some readily fusible flux, such as powdered fire-clay, or borax and fine sand. This serves the double purpose of keeping the air from contact with the steel, thus preventing undue oxidation, and also enabling the forgemen to weld up under the hammer the fine pits and blow holes which are at all times most liable to exist at the surface of the ingot.

Crucible steel, which is to be used in bars of ⅝in. diameter and above is generally finished right through from the ingot in this first heating by means of the steam hammer or the tilt; while smaller sizes and steel which has to be cold drawn or cold rolled, must be forged into a billet of convenient size and section, but in both cases the preliminary process

is the same as that described. Steel which is not finished at the first heat is usually made into billets of 1½in. to 2in. square, and in this state the ends are again broken to see that the steel has not been damaged in the process. The billet is then re-heated and rolled into proper size and section for the following process either of cold rolling or drawing.

The heat treatment of crucible steel requires the greatest care from beginning to end, and none but workmen of long experience in this special work can be employed on it. The most fruitful cause of faults in crucible steel is found in its heat treatment, for being, as a rule, of high carbon, the temperature at which the steel exhibits signs of coarse crystallization due to overheating, is not very high as compared with that of commoner steels, and though the after processes of hammering, re-heating, and rolling, do to some extent neutralize the bad effect, yet this cannot be entirely removed by any process short of re-melting.

Mechanical Work.

If in the process of hammering and of rolling, the steel is worked at too low a heat, or heated too quickly, it may develop internal fractures, seams, rokes, or crushes, most of which become visible only when the manufactured article is nearly completed.

Cold Drawing.

Cold rolling and drawing are, of course, well known processes, and are of such nature that there is very little risk of the steel being injured by the actual cold work. The billets being first hot rolled into strips or wire rods, the furnace scale is removed by pickling in dilute acid, the acid is then neutralised in lime water, and the billets thoroughly scoured. They are then heated in ovens to about 400° centigrade in order to drive out the last traces of acid and occluded hydrogen. The rods are then pointed and drawn through solid dies down to the finished size. Sometimes it is necessary to draw the wire several times, in which case it becomes necessary to anneal the wire at regular stages. for the effect of cold work is to harden the steel, and if done to excess will render it so brittle as to be readily broken by hand even in comparatively large sizes. The effect of cold work not only hardens the steel, but when combined with proper annealing, and followed by hardening and tempering, makes it possible to produce crucible steel wire of such enormous tensile strength as is quite unattainable with any other steel.

Annealing.

Merely to mention the word "annealing" is a sure way to arouse discussion, so many are the opinions and theories held on the subject, first the temperature, then the form of furnace, and the length of time and many other phases of the question are considered open to doubt.

According to my own experience, the temperature most certainly must be regulated by the carbon contents of the steel to be annealed. The higher the carbon, the lower the annealing temperature. But at most, the actual range of annealing heats for all classes of steel is a somewhat narrow one, lying between 800° and 1,000° centigrade, or between bright cherry red and orange colour heat. As regards the length of time the process should occupy, this is in a great measure decided by the quantity of steel to be annealed at one time. The two dangers to be avoided are, under annealing, both in time and temperature, leaving the steel too hard or of irregular hardness, and over annealing, whereby it becomes coarse grained, and in extreme cases even shows signs of being burnt.

As to the construction of an annealing furnace, what is required is one capable of being steadily and evenly raised to a full red heat, and having a muffle chamber which can be effectually closed against the admission of air. Another point worthy of remembering is that annealing should be done on a rising—not on a falling temperature. That is to say, if the annealing heat of a certain steel be 800° centigrade (good cherry red), then the steel must be heated to that temperature, no higher, no lower, and after remaining for some hours, is allowed gradually to cool down. Every grade of heat has a certain and fixed effect as regards molecular condition on every temper of steel; the annealing temperature of every steel is a constant one, and if that point is passed other and often detrimental heat effects are obtained, and these are not eliminated by the slow cooling. If we examine the etched surface of any heat-treated steel with the microscope, we shall see the actual result in size of grain. etc., which is characteristic of the maximum temperature at which that steel was last treated, provided no mechanical work has been allowed to affect the result.

The heat treatment of crucible steel requires always the greatest care, because of the higher percentage of carbon it contains, and its consequent susceptibility to the evils of overheating.

METAL STEELS.

I have so far said but little of steels having as their hardening agent some other element than carbon. Unfortunately, I cannot give much more than general information on this section of my subject, because the methods of alloying these elements with iron to form steels, are to a very great extent founded on secret formulæ and methods. As a general rule, the rarer metal is conveyed into the iron in the form of an alloy of iron very rich in percentage of the hardening metal.

Chromium.

This metal is usually combined with iron to form an alloy containing about 10 to 15 per cent. of chromium. A sufficient quantity of this alloy is introduced into the crucible when the charge of iron or mild

blister steel has become melted, and in a very short time the chrome steel is ready for casting.

Chrome steel has a very high melting point, and requires very great care in melting, owing to the readiness with which chromium oxidizes and is lost in the flux, which flux has a very strong action on the material of which the crucible is made. Chrome steel always contains a certain amount of carbon, indeed, it has been stated, and with some truth, that the hardening value of chromium is an indirect one, enabling the carbon to remain in the state of "Hardening Carbon" more effectually than would a higher percentage of carbon unaccompanied by chromium. An ordinary chrome steel having ·80 per cent. chromium, would probably contain about ·40 per cent. carbon, and would have probably the same hardening effect in a cutting tool as a carbon steel containing 1·40 per cent carbon. Chrome steel, in spite of its hard nature, forges very easily, but should not be worked much above cherry red heat. However carefully chrome steel is annealed, it yet retains its hardness, so that it can be machined only with great difficulty; it is, therefore, most suitable for tools which can be brought very nearly to their finished shape and size by forging. The characteristic property of chrome steel is a very high degree of hardness combined with much greater tenacity than a carbon steel of the same hardness could have. It is capable of being hardened and tempered, but this requires more care and experience than the ordinary toolsmith possesses.

Chromium is often used in conjunction with other metals to produce steel, as for example, in some of the "high speed" turning tool steels, which are at present creating such a large amount of interest. Of this I shall have occasion to speak later.

Tungsten.

Tungsten is an element which can be readily prepared, and there is not, therefore, any serious difficulty in alloying it with iron. Tungsten steel is of very considerable commercial value, first, because of its extreme hardness, and secondly for its valuable magnetic properties. Tungsten increases the strength of steel enormously, but its elasticity is very low. It is readily added to the charge in the metallic state, but as the metal is usually in a finely divided state, it is incorporated with some carbonaceous vehicle before being added to the charge in the crucible. This serves the double purpose of protecting the tungsten from loss by oxidation, and of creating a reducing atmosphere within the crucible.

The fracture peculiarly characteristic of tungsten is of a very close texture, and very sharply at right angles to the direction of the blow by which the bar is broken, and its lustre is very dull and slaty. Carbon is usually present in tungsten steel, but the quantity, as also is that of tungsten itself, is extremely varied. Tungsten running from 1 per

cent. to about 8 per cent., and carbon from ·65 per cent. to 1·75 per cent. The proportions being about ·3 per cent. of carbon to every 1 per cent. of tungsten. Tungsten steel, like chrome steel, is very easily spoilt by overheating, and should be forged between dark red and full cherry red (500° to 900° cent.) Tungsten is the basis of practically all the so-called self-hardening steels. In making tools from this steel it is not necessary, nor is it possible, to harden by quenching in water; but after being formed by the smith, should be again heated to a cherry red and allowed to cool naturally, or may be cooled in a blast of air, but on no account must the hot tool be brought into contact with water, or moisture of any kind.

Aluminium.

This metal having the property of reducing the melting point of steel is only used as a means to that end, as for example, in the manufacture of crucible castings in mild steel. For this purpose a portion of metallic aluminium is dropped into the crucible just before casting. This, in lowering the melting point, makes the now superheated steel commence boiling, thus driving out the contained gases and tending to produce sounder castings. Only small traces of the metal are found on analysis, most of it passing into the flux.

Titanium.

Titanium in steel is very rarely met with, indeed, I doubt if any firm at the present time makes a steel of this character. Titanium is one of the most difficult metals to deal with on account of its high melting point. It occurs in many makes of pig iron, but its practical value in connection with steel has yet to be found.

Molybdenum.

Molybdenum is occasionally used in steel, but so rarely, that when found by the chemist, its presence may be due more to accident than design, unless present in rather important amounts. Its effect on steel is very much the same as that of tungsten. Of late it has been used in conjunction with chromium and tungsten in the high speed turning tool steels.

TREATMENT BY THE CONSUMER.

I have thus far endeavoured to give a concise account of the process by which crucible steel is made, this may be, and I hope is, of considerable interest; but in order to arrive at something of practical use, I think we may, with advantage, follow the steel after it leaves the maker's hands, into the hands of the user, and in doing so I shall avoid, as I have already done, the strictly scientific side of any questions which arise. Valuable as is the scientific understanding of the principles and practice of steel making, more valuable, especially in the case of Crucible Steel, is an exact knowledge of our requirements, and a practical understanding of the methods by which we can obtain them. Some of the

best steel ever sent out of Sheffield has been made by men who knew nothing of science and its wonders. Indeed, for the production and proper use of Crucible Steel, scientific knowledge is not the one thing needful to achieve success.

This section will, I fear, be somewhat desultory for I have tried, without success, to bring it into concise and systematic form.

Though not coming strictly under the term "Treatment," the actual ordering of Crucible Steel is often the first cause of trouble to the consumer. It is, I regret to say, very usual for Crucible Steel orders to be received which simply specify the weight and size of the steel required, leaving the poor manufacturer to guess at the kind of work it has to do; the aggravatingly vague description "for tools" often being added. There can be no good reason for this reticence. When ordering Crucible Steel, for his own sake, the user should give every possible information to the manufacturer. The more fully this is given, the more certainty is there that he will receive the right kind of steel for the purpose he orders it, and also the less chance has the steelmaker of being blamed for the shortcomings of his steel.

The Smith's Shop.

Except in very large works, where special shops are run for the purpose of making and repairing tools, there is much risk of tool steel being spoilt by the smith. Accustomed, perhaps, in his regular work, to the use of common mild steels or iron, he has only a very casual sort of acquaintance with Crucible Steel, and of the special care with which it must be treated. Ordinary Crucible Steel, of a temper suitable for tools should be gradually heated, with frequent turning about in the fire until it reaches a good full yellow, it may then be forged into the required shape, and if this can be done at a single heat it is better to do so. In any case, work must not be continued after the steel has cooled down to dark red. If the tool cannot be shaped before this point is reached, it should be again heated and then finished at a proper heat. All mechanical work on steel between dark red and black hot leaves it brittle and liable to break in hardening.

The forging of steel tends to produce internal and irregular strains, and this is especially the case with hard tool steels, even when finished above the critical temperature of dark red. For this reason it is advisable, that after the smith's work on the tool is completed it should again be raised to a good cherry red heat and allowed to cool naturally. The tool is then ready for filing, milling, or grinding to the finished form and size.

HARDENING AND TEMPERING.

Practically all carbon tool steels require hardening, and usually are tempered as well. It is, of course, unnecessary to define the terms "Hardening" and "Tempering," and it is not possible to explain the

actual change which takes place in the nature of the steel when it is submitted to these operations. There are so many theories, all so different, claiming to explain these phenomena that it would be out of place to consider them now.

To harden steel, it is necessary that it should be raised to a certain heat and then cooled quickly in water or in some other liquid. The tempering of steel requires the hardened steel to be very carefully raised to a temperature considerably lower than visible red heat, followed by sudden quenching in cold water.

The general principle of hardening is that steel shall be carefully and regularly raised to a proper temperature; in cast-steels of ·75 per cent. carbon and above this temperature is about 850° centigrade, or a good cherry red. It is generally thought, by all but the comparatively few skilled hardeners, that to get the heat anything between full red and orange is quite near enough—especially for tools which are afterwards to be tempered. Now this is a very serious mistake. To get the perfect result, the exact and proper heat should be employed, at none other will the steel do its best work. If the temperature be too low, the full hardening will not be reached and the tool will either be unevenly hardened or altogether soft; if too high it will probably be burnt, or at any rate weakened and made too brittle. Another and very important requirement is that the heat should be gradual and uniform. The skilled tool smith is able to heat his work properly in the ordinary hearth by careful attention and by frequently turning it in the fire; but the ideal method of heating is by means of a properly-constructed gas muffle, and, wherever the size and form of the tools will allow, this should be done. When once the right heat has been reached, and without a moment's delay, the tool is removed from the fire and plunged into cold water, kept moving until it is no longer visibly red, and allowed to become quite cold before being withdrawn from the water. In hardening large tools, weighing above four or five pounds, it is safer to leave them in the water for several hours. Never, under any circumstances, harden a tool on a falling temperature.

It may happen that a tool which should harden at a bright cherry red heat has, by forgetfulness, been allowed to reach an orange heat. If so, do not think that by allowing it to cool down to cherry red, and then quenching, it will give the proper hardening; let it become quite cold naturally, then heat to the right temperature and quench directly it reaches that temperature.

The main truths of hardening might be put into a single sentence, something like the following:—"Raise uniformly to the right heat, cool suddenly and completely."

Comparatively few classes of tools are used in the hardened state and without being tempered. A hardened high carbon steel, while it has

the maximum of hardness possible has its elasticity much reduced, and for most purposes this would render the tool useless. In order to guard against this it is necessary to sacrifice a little of the hardness in order to secure greater toughness, and this is done by "tempering" the steel. The process of tempering consists in heating the already hardened tool once more, but this time to a very low heat, considerably lower than visible red. The amount of heat cannot be judged as in hardening though it is done in a similar manner.

When bright steel is heated in the air and below red heat, certain changes in colour take place. Beginning at a pale yellow, gradually darkening, then through the different tints of brown, followed by purple, and then to blue and dark blue, a complete scale of colours can be produced. In all carbon steel these colours are produced in exactly the same order, and, as each colour appears always with the same temperature, advantage is taken of the fact to gauge these low temperatures so as to utilise them for tempering the steel. I might say here that tempering is often called "letting down," and is really a very correct term to use, for it is actually a "letting down" from extreme hardness to elastic hardness. In actual practice, the following is the usual method: Part of the working surface of the tool is cleaned of its scale and made bright by rubbing with emery paper or a piece of sandstone; it is then carefully heated, watching for the exact moment when the first colour appears, this will be quickly followed by all the range of colours in their usual order. Immediately the required colour becomes visible, the tool is plunged at once into cold water. It is, of course, impossible to give here information which can be applied in every case, but on the Table (page 72) is given a list of the principal classes of tools, together with hardening and tempering data as used for each.

Sometimes, especially in the case of small tools, the process of hardening and tempering can be carried out at one operation, by quenching the tool at the hardening heat, and just as it ceases to be visibly red, withdrawing it from the water, quickly rubbing with sandstone, then watching carefully for the temper colour which is drawn out by the heat remaining in the body of the steel; directly the colour appears the tool is quenched right out in water. This method, however, is risky with large tools and those having irregular form, because of the uneven contraction and expansion, which may result in breakage.

Quenching Liquids.

In general work it is the rule to use water as the cooling liquid, but variations in the extent of the hardness can be obtained by using other liquids, and even by altering the temperature of the water itself. Thus, in some classes of steel, very liable to break on hardening, the danger can often be avoided by quenching in hot water. Other liquids are, whale or lard oils, tallow, both melted and solid; sulphuric acid, both dilute and full strength; soap water, soda solution, and solution of

common salt. Each of these have their special uses; for example, in hardening and tempering springs, oil is used for quenching the heated spring, and when cold it is taken out and thrust into a flame; when the oil takes fire, and as it burns off, also tempers the spring. The use of sulphuric acid for hardening requires very great care, so as to avoid splashing this dangerous liquid on the person. It has the advantage of giving much greater hardness than any other liquid in general use, and it is also claimed (I think rightly) that there is less liability of breakage to the tool during the process of hardening. The most important, however, is a solution of common salt in water. Usually this is called a saturated solution, but the Sheffield workmen know nothing of saturation. They use as their test a potato or an egg, either of which will float when the solution is deemed to be of sufficient strength. This is equivalent to a specific gravity of about 1·5.

The usual plan in salt-hardening is to have about 20 gallons of the solution in a wooden tub fitted with a loose cover. The tools, when fully heated, are plunged into the salt and kept moving till cold enough to handle; they are then quickly transferred to a tank of clean cold water where they remain till absolutely cold. Salt-hardening is chiefly used for such articles as require to be made "dead hard," and are left in that state without being tempered, such, for example, as files, drawing-dies, and some kinds of cutters. Another advantage of salt-hardening is, that it enables one to use a steel containing considerably less carbon than would be necessary for plain water hardening, thus getting the required hardness combined with a tougher material.

TABLE OF TEMPERS SHOWING HARDENING AND TEMPERING.

Nominal Temper.	Carbon.	Class of Tool.	Welding Capacity.	Hardening.		Tempering.	
				Heat Colour.	° Centigrade.	Temper Colour.	° Centigrade.
RAZOR	1·50	Small Turning Tool	None	Low Red	700	Light Blue	290
TURNING TOOL	1·25	Turning and Planing Tools	Requires extreme care	Low Red	700	Brown to Blue	265
		Small Drills	,,	,,	700	Dark Straw	245
CUTTER ...	1·15	Cutters	With care	Low Cherry	800	Dark Straw	245
		Large Turning Tools	,,	,,	800	Straw	230
CHISEL	1·00	Cold Chisel	With care	Cherry	850	Light Blue	290
		Hot Sates	,,	Full Cherry	900	Light Brown	250
		Punches	,,	,,	900	Straw	230
SATE	·85	Cold Sates	Without difficulty	Full Cherry	900	Blue	295
		Large Taps	,,	,,	900	Straw	230
		Smith's Fullers, &c	,,	,,	900	Light Straw	220
DIE	·70	Large Dies	Welds easily	Full Cherry	900	Brown	255
		Boiler Cups	,,	,,	900	Light Blue	290
		Hammers	,,	,,	900	Tempering not necessary	...

The process of hardening requiress the greatest care from beginning to end, an absolutely certain judgment of heat-colour, careful manipulation, and a thousand and one little tricks and devices which experience alone can teach, most of which have to be learnt or devised according as the shape and size of the tools may require.

There are two essentials to perfect hardening, viz., absolute and regular hardness, and avoidance of breakages. The former is obtained by a proper study of cause and effect, the latter, as I have said, by constant watchfulness and experiment as occasion requires. The process from beginning to end must be adopted to suit the size and shape of the articles. Most tools are irregular in thickness in one direction or another. Care must, therefore, be taken, so to manipulate them when heating, as to avoid the thin parts being fully heated before the remainder has arrived at the right temperature. So, in cooling, the thicker parts, wherever practicable, must enter the water first. This causes the article to cool more equally, while if the thin parts be first to enter the water they are cold first and the thick parts being last to cool must contract at the expense of the thin parts, thus setting up all the elements of fracture. By this I do not, of course, mean that there should be any delay in plunging the whole of the article into the water; put in the thicker part first, where possible, but let the immersion of the whole be continued without any pause, or a fracture is almost certain. Another important point is that of moving the article about while it is in the cooling liquid. By so doing you prevent the formation of a non-conducting steam cushion between the hot steel and the cooling liquid. Care must also be taken not to allow any part of the article to come above the surface until the whole piece is properly cold. This last remark does not apply to such tools as require only the point or the cutting edge to be hardened. In such cases, only so much of the point should be heated fully as is required to be hardened, and if plunged just so far into the fire there will be a nice graduation of heat from the full red at the point gradually reducing to black heat in those parts which are to remain soft. The tool is then held vertically, and the point or edge only plunged into the water, keeping it moving horizontally and slightly dipping vertically at the same time. Cold chisels require very careful observance of this rule, and it is important in this and in similar cases, that the process of tempering should be carried out separately. First harden the tool, then temper it either by heating in the hearth, or, in the case of small articles, a piece of scrap iron or steel, say about 10in. by 6in. by 2in., may be made red-hot, and the hardened pieces placed upon it, after having been brightened. The temper-colours can then be easily watched so that the articles can be cooled off in water at the right moment.

For those who wish to study this very intricate subject of hardness and hardening, I cannot recommend a better guide than a paper read before the Iron and Steel Institute by Mr. Axel Wahlberg, of Stockholm, in May and September this year, entitled, "Brinell's Method of Deter-

mining Hardness and other Properties of Iron and Steel." The paper is a most lucid one, treating most exhaustively of the results obtained by varying the temperature of the steel and the nature of the cooling liquids employed.

THE SELECTION OF STEEL.

There can be no doubt that the success of all applications of Crucible Steel depends chiefly on the selection of the steel used for various purposes. This is, of course, in the hands of the steel manufacturer; but it is of the first importance that he should know exactly for what purpose it is required. As a general principle, and apart from any question of quality, we should select the lowest temper which will fulfil the requirements of the work to be done. For, as the difficulty of treating the steel increases with the carbon, we can obtain wider limits by using the lowest possible temper, and, provided the hardening is properly done, the risk of breakage in use is much reduced.

HIGH-SPEED TURNING TOOL STEEL.

No paper on Crucible Steel would at the present time be complete, which did not speak of his new class of tool steel which is being used for machine work at very high speeds. This class of steel came into prominence at the Paris Exhibition last year, when the Bethlehem Steel Company shewed tools at work on mild steel shafting at a cutting speed of 150 feet per minute without lubricants. So great was the strain on the tool that its point was distinctly red hot, and the turnings, when cold, were of a dark blue colour, an evidence of the great heat generated.

As a matter of fact, when working at this speed, the tool does not actually cut at all, but wedges off the turnings.

This exhibit naturally aroused very great interest among all who saw it, and it was not long before steel of this nature was being produced by several other firms.

While the composition of the Bethlehem steel cannot be said to be new, yet the results obtained by their original method of hardening made it possible to arrive at this wonderful result, which opened the eyes of steel makers and engineers to the immense possibilities lying in this new direction.

The tool steel of the Bethlehem Steel Co., or—to give the inventors full credit for their ingenuity—the Taylor-White steel, is an alloy containing chromium, tungsten, and molybdenum, in proportions varying according to the kind of work they have to do. The proportions may be from ·75 chromium, with 4 per cent. tungsten or molybdenum, or else a mixture of the two latter with chromium. This would be suitable for machining mild steel at the highest speed, while for working hard steel or chilled iron the steel would contain about 3 per cent. chromium, 5 per cent. tungsten, and 4 per cent. molybdenum. It will be seen

from this, that the composition of this steel is not unlike those long known as "self-hardening," but, as I have already stated, which steels were never submittted to any other hardening process than that of simple cooling in the air or under a blast of air. But, by the Taylor-White method of hardening such steels, a very great advance was made; for, while confirming the fact that this steel heated up to 900° centigrade, and afterwards allowed to cool, would be unfit to use, they discovered a remarkable new method of hardening. They heated the steel to about 1200° centigrade, then rapidly cooled it in a lead bath down to about 800°, keeping it at that temperature for about ten minutes, followed by natural slow cooling in lime or some other inert non-conducting powder. When quite cold it is re-heated to worm red and allowed to cool in the open air. The tool, during this rather complicated heat treatment, is protected by being covered with a suitable flux, for unless so protected it would be necessary to grind off a certain amount of the surface, which will have been injured by oxidation in the process.

Tools prepared in this manner have not the maximum of hardness possible, but they become of such enormous strength that it becomes possible to use them for such severe strains, This method of hardening requires special care and very exact observance of the necessary temperatures; but, if the success of other makers' steels of this class is any guide, it appears as if some of the details of Taylor-White's method are unnecessary.

There are, to my certain knowledge, three brands of high speed tool steel being made in Sheffield, and their results are equal, if not superior to, those of the Bethlehem Company; and in addition to this, I may say, the method of hardening is very simple, and can be carried out by any toolsmith who is accustomed to working high carbon steel. This most recent method has for its foundation the main principle of Taylor-White's process, viz., the importance of high temperature. The steel is heated to a bright yellow heat (1200° cent.), and is then either cooled in the air or under a blow pipe; then, after being ground, it is ready for use.

It is very probable that all the steels made for this purpose are very similar in composition; but it is not possible to give the exact figures. At least, the hardening of the English steels is so much simpler that they ought to have the preference over foreign steels.

Having thus endeavoured to give you in as complete form as possible, an account of the manufacture and treatment of crucible steel, I cannot close without asking you to excuse the somewhat disjointed way in which I have placed the matter before you. The subject is a vast one, most of it untouched by scientific research, owing much of its value to the many failures and the long experience both of makers and

consumers of crucible steel. Chemical analysis is by no means a sure guide to the student of crucible steel; but it is to be hoped that before long, more certain knowledge of its many problems will be reached, and I have no doubt that by chemical research and the microscope, aided by some such method as Brinell's for systematically measuring hardness, we shall in time arrive at that much-desired stage.

THE DISCUSSION.

THE PRESIDENT intimated that the author had laid a large number of samples of crucible steel upon the table and would be pleased to answer any questions members might ask after examining them. He called upon Mr. Silvester to open the discussion.

Mr. H. SILVESTER: I should like to express my appreciation of the paper, and of the very admirable description we have received of the crucible process. I have never listened to a paper which gave a more comprehensive idea of the Sheffield system, and Mr. Flather must have been at great pains to give us so much information. I am sure every member of the Institute is greatly obliged to him. I have one or two questions that I should like to ask Mr. Flather as to whether it has yet been found possible to substitute very fine basic open-hearth steel in any instance for Swedish iron in the cementation process. Some years ago I was connected with a firm making basic open-hearth steel, and a very fine quality of soft steel was being produced. One of the partners of a Sheffield firm of tool steel makers on one occasion I remember came over to inspect the furnaces, with the object of starting a basic open-hearth plant, to manufacture high-class soft steel to be used instead of the Swedish iron, as described by Mr. Flather. Nothing definite was done at the time, and I should be glad to know if Mr. Flather has any information upon the same point. Has very pure dead soft steel in any way taken the place of Swedish iron? I have been very much interested in the description of the hardening and tempering of crucible steel. On page 61 I find it stated that the percentage of carbon found in this class of manufactured metal ranges from about ·25 per cent. up to nearly 3 per cent, but in the very interesting table of tempers I observe that there is no class of tool included with a higher carbon than 1·50 per cent., and this is described as "razor" temper. I should like some information, if Mr. Flather will give it us, as to the class of tools in which this very high carbon steel is used. Say with carbon from 1·75 per cent. to 3 per cent.

Mr. G. MELLAND: I have been greatly struck by Mr. Flather's remarks under the head of "temper," and particularly by that portion in which he points out that impurities in crucible steel do not appear to

have the same action, or to be deleterious to the same extent, as in steels made by, for example, the Bessemer and open-hearth processes. He observes, when treating upon this point, that "a crucible steel having ·80 to ·85 per cent. carbon will have about the same temper as English Bessemer steel of ·60 to ·65 per cent. carbon, while a Swedish Bessemer steel would require to have about ·70 per cent. carbon to reach the same temper." I should like to suggest to Mr. Flather that this difference is due to the presence of the extra impurities in the Bessemer and open-hearth metals, which are not found in the crucible steel. Thus an English Bessemer steel would show a certain amount of phosphorus and an amount of manganese on analysis, which would have a hardening effect; a basic Bessemer steel would have rather more manganese, and would probably be harder, although of course phosphorus also is a hardening element. A Swedish Bessemer steel would require more carbon than either of the other two processes to attain the same hardness, and my suggestion is that the variety pointed out by Mr. Flather is not due to any intrinsic difference in the steels themselves, but is to be attributed entirely to the varying amounts of impurity in the different classes of steel.

Mr. H. W. Waldron: With reference to impurities in tool steel, I can quite bear out, from what little experience I have had, that some crucible steels will stand a rather remarkably high percentage of sulphur, and in some cases, of phosphorus also. Further, while in mild steel a small rise, say of 1 per cent., in the percentage of manganese, has little or no deleterious effect, a similar increase in the percentage of manganese in crucible steel will do more harm than a proportionate increase in the percentage of phosphorus. I have often found this to be so. Take the case of crucible steel for the manufacture of axes—I have known steels employed for this purpose which have possessed a fairly high percentage of phosphorus and sulphur and a low percentage of manganese, and yet have given the most satisfactory results. An increase of manganese in these steels appeared to increase the forging qualities of the material, but it had a tendency to cause water-cracks. There can, I think, be little question that impurities produce different results in crucible steel to those they produce in ordinary mild steel.

Mr. Frank Moore: At the close of his paper, Mr. Flather, under the head of "High speed turning tool steel," referred to the remarkable exhibit at the Paris Exhibition last year, sent by the Bethlehem Steel Co., of the United States, made by the Taylor-White process. He states that tools made of this steel were at work on mild steel shafting, cutting at a speed of 150 feet per minute, and that so great was the strain on the tool when working at this speed that it did not cut but wedged off the turnings. I should like to enquire what is the difference between wedging and cutting; I cannot see much difference between the two

operations except, perhaps, that one would produce rather a rough surface and the other a smoother surface.

Mr. FLATHER: In reply to the first question, put by Mr. Silvester, as to whether it has been possible in any instance to substitute basic open-hearth steel of good quality for Swedish iron in tool steel manufacture, so far as I have ever heard, and so far as my experience goes, I have never heard of such substitution. It is in some cases not entirely unknown for a good quality of acid Siemens' steel to be converted for mechanical purposes, but not having as its object the production of tool steel. For the purposes of certain classes of machinery used, for example, in some of the textile trades, bars of English Bessemer steel of about ·10 per cent. to ·15 per cent. of carbon are frequently converted, but they are not heated sufficiently long for the carbon to penetrate right through, so that the process is really more like case hardening than anything else. For this purpose the bars are placed in long pots, or in the actual furnace chamber, and are partially converted or left with some "sap" in them, to use a Sheffield steel-maker's term, that is with a very mild centre. So far, however, as the employment of inferior qualities of steel or iron are concerned as admixtures in the crucible process, such as suggested by Mr. Silvester, it has certainly not come within my knowledge Mr Silvester asked a question as to the classes of tools for which steel containing as high a percentage of carbon as 3 per cent. would be employed, and he seemed to entertain some doubt as to there being 3 per cent. of carbon in any crucible steels. Among the samples which I have placed on the table, however, is a piece of ingot made at our works, which contains 3·2 per cent. of carbon as actually tested by combustion, and I will undertake to say that upon analysis carbon within the limits of 3 to 3·25 per cent. will be found in it. The steel referred to is certainly a speciality. It is used for wire-drawers plates, and is used in an entirely unhardened state. It would, of course, be impossible to harden it, that is if made red hot and then plunged into water it would fly into a thousand pieces like so much glass. Mr. Melland made some remarks respecting crucible steel and its equivalent tempers in steel made by the open-hearth and Bessemer processes, and in those remarks he was perfectly correct. I hope I did not convey in my paper the general idea that the difference referred to was intrinsically due to the crucible process itself What I meant to say was just how Mr. Melland put it, namely, that owing to the impurities in the different classes of steel, crucible steel will "carry more carbon" than will an English Bessemer steel. In the same way a Swedish steel will carry more carbon than English steel. It is a peculiar fact, but one which analysis will amply confirm, that in certain classes of tool steels there is a very high percentage of one or other of the impurities. Sulphur is a very favourite impurity found in crucible metal, and remarkable as it may seem, I have even known in some of the steels made by my own

and other Sheffield firms an amount of sulphur that would have condemned a Bessemer steel. And yet this same steel in actual use has answered every possible purpose and proved fully as efficient as it would have done if there had been no high percentage of sulphur present. Mr. Moore asks me to explain the difference between wedging and cutting in the effect of tools made from the Bethlehem Steel Co.'s new steel at the Paris Exhibition when employed upon turning mild steel shafting, working at a great speed. I am afraid that any answer to such a question would be more an academic one than anything else. Speaking absolutely literally, Mr. Moore is quite right, that to cut or wedge is really one and the same thing; but the cutting of iron and steel with a comparatively blunt-edged tool approaches more nearly to an expression of the term wedge. If for illustration a piece of wood is cut through with an edge tool it comes away with a clean surface, but if severed with a wedge it presents a raw surface, and it was just this difference which an examination of the turnings in question showed. Perhaps a better term to have used would have been "split off;" some of the turnings presented a very smooth and clean surface, and others appeared as though they had been literally split off the shaft or whatever they may have been turned from. It will be remembered that I have already remarked that so great was the strain on the cutting tool that its point was red hot, and that the turnings when cold were of a dark-blue colour, an evidence of the great heat generated.

THE PRESIDENT: I am quite sure we have all appreciated Mr. Flather's able and interesting paper very much. Mr. Flather's father is a very old friend of mine, and I knew that anything that proceeded from his son in connection with crucible steel making would be of a very instructive character, and we have not been disappointed. I was very much struck with the early part of the paper in which Mr. Flather laid it down that the actual process as practised to-day is worked on the same lines as those of the original inventor, who was born in 1704. Thus very little alteration has been made in the furnaces employed for two centuries, and very little improvement, I take it, has occurred in their style or construction. In my presidential address I called attention to the comparative little progress which has taken place in the construction of furnaces in the iron and steel trades, and the limited amount of economies which have been effected in the consumption of fuel. More especially has there been a want of progress in our puddling and heating furnace construction. Mr. Flather's paper makes it clear that what I may call the same defect exists in connection with crucible steel manufacture, and it is one which I imagine is capable of improvement. This brings me to a matter which for some time past has engaged my attention, namely, the service which the new University in Birmingham might render to the trades of this district if it provided greater facilities than at present exist for enabling inventors in this part of the Kingdom (who may not have a great deal of spare capital) to

proceed with and prosecute their inventions at small cost to themselves. The University has been established with the object of conferring many benefits upon the Staffordshire and Midland district, and I should very much like to see something done in the direction of which I have been speaking.

I now have to propose that our best thanks be given to Mr. Flather for his paper.

Mr. W. Brooks, who seconded the vote of thanks, remarked that the paper had been what he considered one of the best which had ever been read before the Institute. To any one using machinery for the purpose of removing metal, either by milling, turning, planing, or boring, such a clear and detailed description of the methods by which the tool steel is manufactured must be of prime interest. He proceeded: With regard to the extraordinary tool steel shown at the Paris Exhibition by the Bethlehem Steel Company and mentioned by Mr. Flather, I was greatly interested that Mr. Flather should have stated that to his own knowledge there are at the present time three brands of high speed tool steel being made in Sheffield, equal, if not superior, to the material of the Bethlehem Company. Now this seems to me a splendid point gained for this country. British consumers would, I should imagine, certainly rather use native steel and keep the trade in this country than buy it in America, thereby encouraging foreign competition. It also occurs to me that the invention of this magnificently hard tool material, the chief feature in the hardening of which is, Mr. Flather tells us, high temperature, will be an immense boon to machinery and engineering firms who have exceedingly hard cutting work to perform. For example, it appears to me that it will be largely unnecessary in the future to shoulder down shafts, &c., since these tools will turn the work down from rolled bars and thereby save the cost of forging. This is only one example out of many which might be mentioned as showing the advantage which the new tool steel will confer. I well recollect some years ago having to turn a cast-iron ram, made of very hard metal, 12 feet long by 24 inches diameter. We first employed upon it a tool made of the best ordinary cast-steel; but we found that this tool would not keep its edge, and required re-grinding several times while traversing the first three inches along the ram. A tool made of R. Mushet's steel was then substituted, and to our surprise, this tool completed the remaining distance of 11ft. 9in. in length without being taken out once, or being re-ground. Up to now I know of no better steel than Mushet's, made by Osborns of Sheffield, and I have tried nearly every class of tool steel on the market. From what Mr. Flather says, however, a new era in tool steel making seems to have dawned If so, it is most important.

The vote of thanks having been put and carried,

Mr. Flather, in replying, said: I am more than repaid for any trouble I have taken in the preparation of this paper by your very

patient hearing and very friendly reception of it. It has given me extreme pleasure, and it always does, to impart any information I may be possessed of to others interested. The doing so gives me a hope that I may also receive any information I may require, and I am always wanting further knowledge from someone better informed than myself. One is naturally, or ought to be, deeply interested in all the processes and technicalities of one's own business or profession, and it always gives me peculiar pleasure to explain or impart to others information about my own business which I may legitimately make known without injury to the firm with which I am connected. I think if there were more of this class of feeling between manufacturers and inventors, more of this mutual interchange of thought, and more confidence in one another, it would be better both for the trade and industry of the country. Not only would manufacturers and producers' esteem for each other be increased, but our general intelligence and inventive faculties would be quickened, and the British iron and steel trades would be increasingly able to hold their own in the international struggle for existence and supremacy. I may say, in conclusion, that the object of my paper has been rather a practical than a scientific one; I have endeavoured to give you a narrative of what the crucible steel trade is rather than to raise a discussion on the scientific and technical side of tool steel treatment and manufacture. If I have made any undue allusions to the manufactures of my own firm in particular, I beg to assure you it has been inadvertent and not intentional.

CORRESPONDENCE.

Mr. Thomas Turner: I had intended to be present this evening at the reading of Mr. Flather's paper on "Crucible Steel," but fear it will be impossible.

The paper treats with a subject which has received little attention at the Institute meetings, and deals with the matter more from a steel user's than a steel maker's point of view. As there are many more users than makers cf crucible steel, this is likely to make the paper more generally interesting.

Mr. Flather refers to many points which should lead to interesting discussion; for example, the importance of selecting the right kind of steel for the particular purpose in view. Much of what is called bad steel is merely steel used for a wrong purpose or wrongly prepared for the purpose. It has long been pointed out by practical men that steel should not be hardened on a falling temperature, and to this point Mr. Flather makes special reference. No doubt the explanation is to be found in the critical temperatures which are now known, and to the absorption or elimination of latent heat at these temperatures, with a corresponding change of internal structure.

Mr. Flather refers to the surface colours which are practically used as a guide during tempering, and in his table on page 72, as is usually done, he gives temperatures corresponding with these colours. A few days ago I came across copies of a little-known paper, which I read some years since before the Birmingham Philosophical Society. In this it was shown that these colours are due to oxidation, and that, while they are to a great extent independent of the carbon content of the steel, they vary very much according to the time during which the metal is heated, and the colour scale is entirely unreliable unless the metal is always heated at the same rate. I have forwarded under separate cover some copies of this paper, which the members of the Institute may be interested to see. It will be noted that tempering can be quite satisfactorily performed, if the surface of the steel is protected, without any colour indication whatever.

Mr. D. FLATHER: In reply to the letter of Mr. Thomas Turner—

(1.) The selection of steel for the various purposes. This selecting is most necessary, but if it is to be done properly it must be by the steel manufacturer and the consumer together, the former must know very fully the requirements of the latter. The steel maker then, knowing the properties and advantages of all the qualities and tempers of the steel he makes, is in a position to select the fittest for the purpose. Not only this, but he is, or should be, able to give very complete information for the treatment of the steel selected so as to fit it completely for the end in view.

(2.) Temper colours. I alluded to these colours as being very reliable as guides to the workman in tempering steel, and as the process of tempering is usually carried out in a very regular and constant manner it is sufficient to take this scale of colours as a guide.

To enquire fully into the actual phenomena does not come within the scope of this paper. In the interesting pamphlet Mr. Turner kindly sent to me, the temper colours seem rather to be considered as the object to be gained rather than as a means to an end. In my temper list, on page 72, we see, for example, that the colour " light blue " appears three times, viz., for boiler cups, cold chisel, and razor classes. Now it will be plain that the mere fact of tempering any given steel to a light blue will not serve to render it suitable for more than one of those three classes—perhaps not even one. The temper colour is an indication of heat, and in each case a proper heat at which to obtain the perfect tempering which the temper (carbon) of the steel and its purpose require. If you heat the steel in vacuo, or in an atmosphere of hydrogen or other gas, your guide is no longer reliable, but the toolsmith contents himself with heating the steel always in one manner, and under as nearly as possible the same conditions, and therefore using a safe guide gets a sure result.

The fifth (Special) Meeting of the Session was held at The Institute, Dudley, on Saturday, February 1st, 1902.

The President (Mr. Walter Somers) occupied the chair, and there was a large and representative attendance. Letters and telegrams of apology were announced from Sir Benjamin Hingley, Bart.; Sir Alfred Hickman, M.P.; Colonel James Patchett, Mr. G. H. Claughton, and others.

The minutes of the previous meeting were read, adopted, and signed.

Mr. F. J. Millard was elected a member of the Institute.

The President in introducing Mr. Ebenezer Parkes, M.P. (who had recently visited the iron and steel manufacturing centres of the United States of America, on behalf of the British Iron Trade Association), said he was quite sure, from the very large number present, that the members highly appreciated Mr. Parkes's kindness in consenting to address them upon the result of his enquiries and observations, and therefore asked him to deliver his address.

Mr. Parkes on rising was received with applause. He then delivered he following address:—

FOREIGN COMPETITION.

An Address by EBENEZER PARKES, Esq., M.P.

At no time, perhaps, has foreign competition more engaged the attention of the business world than at present. We have already felt the pinch of it in lower prices and diminishing profits; but I am convinced that such is the eagerness with which foreign competitors strive for trade, and such is the development of the business faculty, and the perfection of machinery among our competitors, that we shall feel the pinch much more in the future than we have done in the past, or that we are doing at the present time. It is easy enough for some politicians to lull us into the belief that we are doing better than ever, by giving us an array of figures taken from Blue Books, and so to juggle with these figures that to outsiders they appear conclusive. This is the plan of political economists and of academic persons who are not engaged in trade; but if these gentlemen were to change places with the business man, they would have occasion to alter their views. Almost every man in business is finding his particular trade attacked in turn more or less successfully. If the foreigner suffers repulse at first he returns to the attack again and again, and by greater adaptability and better quality, he manages somehow to find a footing. In no country in the world has the foreigner such a market as he finds in England, both as to her enormous purchasing power and the immunity which he enjoys from there being no protective tariffs here. Great Britain is the happy hunting ground of the foreigner, and he feels secure in his dealings with us because he knows we are so wedded to the principle of Free Trade that any violation which he may make against that principle, in his own tariffs, will not be met by any retaliatiation upon our part.

In discussing this subject we must specially bear in mind that the conditions of British trade are not what they were fifty years—or even twenty-five years ago. Then, we enjoyed a pre-eminence, which allowed us to almost ignore foreign competition. We were easily first as a manufacturing country. We were ahead in inventions in machinery and in the capacity of our workmen. I need not say that this is no longer the case, humiliating as it may be to us to have to admit it. At one time the foreigner had to come to us to learn how to do things; now it is our turn, in a good many cases, to go to the foreigner. Some people rebel against this idea and deny it, but nevertheless it is a fact, as anyone who has an acquaintance with foreign methods will have to confess. We are suffering from our former prosperity and from our feeling of security, and we are apt to imagine that no one can touch us. In a word, we are inclined to be insular in our opinions and in our

prejudices, and it is only by going abroad that we get these opinions dispelled.

I am far from saying it is hopeless for us to compete with this competition. We have still the inventive power, the brain, and the energy among our masters and men to rise to the occasion But, in the words of the Prince of Wales, "We shall have to wake up," if we are to successfully meet this competition which is playing such havoc with our industries. Foreign critics openly boast that with our present conditions we cannot hope to successfully compete with them. Mr. Schwab, among the number, loudly proclaims this doctrine. A distinguished politician, in speaking of British trade the other day, said we should not trouble about pre-eminence, We should rejoice in the prosperity of other nations, for the more prosperous they were, the more we were likely to be. In other words, if my neighbour is prosperous and full of business, I must be content, and rejoice in his prosperity. But that doctrine,' applied to the individual, I am afraid, is hard to swallow. It is rather cold comfort. If the world is prosperous we want, and ought to have, our share in it, or know the reason why. We were at one time ahead of America in the production of pig iron and steel, but now America is producing nearly twice as much pig iron and three times as much steel as we are, and she is still going on by leaps and bounds.

Are we holding our markets? No; we are losing ground in America, Germany, Canada, South America, the Cape, and China. We are engaged in war in South Africa—a great war, an expensive war. What for? To maintain our pre-eminence. But when we have conquered it, shall we maintain our pre-eminence in trade there? In some departments of trade other countries are far ahead of us at the present time in South Africa. We are engaged also in an industrial war. Silent and peaceful as it is, yet it is a war which is fraught with immense issues for the destiny of our country, issues which are sometimes lightly placed on one side by the leaders of public opinion in favour of Imperial questions, which are more showy and more attractive to the public eye. It is a war in which everyone will have to take part, the employer, the workman, the scientist, the engineer, the Consul, the British agent, and last, but not least, the Government of our country. In what trades are we feeling competition? Just a few:—Pigs from America and Canada; steel bars and billets from Germany; sheets from Belgium and Germany; merchant bars from Germany and Belgium; cycles and cycle parts and machinery of all kinds from America and elsewhere; engines (railway and others), boilers, bridges, rolled girders and joists in large quantities; watches, edge tools, tinplates, and a host of other goods too numerous to mention.

We must not make the mistake of under-estimating American, or German, or Belgian competition. To under-estimate is a fatal mistake

alike in politics, in war, aud in trade. Know all you can know, all that it is possible to know, about a business, and then go, if possible, one better. It reminds one of a story I heard in America of an American who wished to embark in a business. He sent an agent all over Europe to collect the best machines he could find, took them to America, studied them carefully, noted the best points of each, and then commenced to evolve something which would be equal, or superior to anything the agent could find. That is what the Americans say. We gave them the ideas and the inventions years ago, and they have applied and developed them in a superior style to ourselves. On the other hand, we have been too fond of the idea that what was good enough for our fathers, or our grandfathers, is good enough for us. That is a fatal principle, and the sooner we give it up the better for us.

Some affect to scorn American machinery and American iron, and say it is "all rotten together." That is a wild statement, but I have heard it made, and it needs no further comment, it only shows the wild ideas some men have. But I want to be fair to British manufacturers. A great many are introducing new and better methods. A great many are improving their production to the highest possible pitch. Many are introducing the most modern machinery and methods of work, and I am afraid in a great many cases the excellence of British manufactures is not sufficiently known. In those cases, they are often handicapped by their goods not being sufficiently advertised in the world by the want of suitable agents to dispose of their goods, or by a want of that thorough freedom of contract between masters and men, which would enable them to produce at the lowest possible cost; besides, another great drawback which British manufacturers have undoubtedly to contend against is the prevalence of protective tariffs in other countries. We are waking up—but only slowly. Many men are travelling now, far more business men are going over to Germany and America than was the case formerly; and a much greater spirit of energy and enterprise if being displayed, and we must live in hope that this spirit will become general. There is one pleasing feature about a visit to America, and that is that the Americans are most generous in their willingness to show a British manufacturer what is to be seen there, and most ready to give him information. In that particular they show a very kindly spirit. I believe they feel secure in their own powers. It is a security which is the result of consciousness of power and unlimited resources.

I have spoken of the *disease*. Now let us look at the remedy or remedies. With regard to our difficulties, there are one or two points we must remember—we must look them in the face, we must not flinch from them; and we must not let our pride stand in the way of a thorough investigation. I don't want to offend anybody by my remarks. I only want to speak the truth, believing that the best and most courageous plan is to look things fairly in the face, and if we are wrong, alter as best we can, and that quickly.

EDUCATION.

In estimating the advantages which America enjoys over ourselves, thus enabling her to take the position she does at the present time, we find that the causes are many; but I will try to enumerate a few of them. One is undoubtedly her better educational system. In this respect America is ahead of us, whilst we are groping about and blundering along to try to find a complete system; and I am sure we all hope that the Government in their next attempt to grapple with this educational problem in our own country, will be courageous enough to deal with the question effectively, even at the expense, if necessary, of sacrificing some so-called vested interests. The subject is a delicate and complicated one, and requires a strong hand to guide it aright. I am far from saying that education is everything. We have some of the most notable examples of eminently successful men in this country and in America, who have not had the advantages of early education such as many enjoy now, and yet by their native energy they have supplied those deficiences by their own exertions, and forced themselves to the top. But there is no doubt that the education of the people is a great national asset, and it should, perhaps, be regarded as the greatest asset a country has. The Americans, by their wonderful cuteness and foresight, have been able to establish, and to a large extent to provide for the payment of, a great national system, co-ordinated so that it shall embrace primary, grammar, and higher technical and university education, all of which is practically free and open to every child whose parent may wish it to be so educated. Long ago, the National Government of the States allotted to each State enormous grants of land for the service of education for ever, and the income from these lands is growing year by year. As Dr. Forbes said:—"Our educational system must be such that in every cornfield and township there must be the foot of the ladder, the upper end of which shall reach the top of the State University. This provision by the Government is supplemented by princely generosity on the part of wealthy people in America in building and endowing Universities. It is, indeed, no common thing for wealthy people in America to give from one to ten million dollars to the cause of education (about two hundred thousand pounds to two millions in English money). Notable recent examples of such generosity are Mr. Carnegie's gifts of 10,000,000 dollars to Scotland, and the same amount also to Pittsburg in the cause of technical education, making about four million pounds sterling of our money in all.

With reference more particularly to technical education, we must admit that this is carried out in Germany and America with a thoroughness and completeness to which, I am afraid, we are somewhat strangers in Great Britain; for in those countries technical education is far more general and complete than anything we have attained to at present. Let us take, for example, the number of day students of fifteen years of age and upwards in one branch of technical instruction (namely,

engineering). We find that in the whole of the technical schools of all the large centres of England and Scotland there are 347 third year students and 52 fourth year students. These two totals refer to technical *day* school engineering students, who put in twenty hours a week, and who begin at fifteen years of age. Now, how does this compare with Germany? We find that in one single German technical school, at Charlottenberg, there are 235 third year students and 242 fourth year students. Those figures refer to the session of 1900, and the students *began* their training at eighteen years of age. The contrast between ourselves and the Continent becomes still more marked when we consider the students who take complete courses. The number of day students taking complete courses in nine German technical schools for the session 1899—1900 was 10,896, and the number of occasional students was 2,536, making a total of 13,432 German students of eighteen years and upwards. This total of thirteen thousand and odd compares with not quite four thousand (or, to be exact, 3,873) day scholars in all the technical schools of the United kingdom of fifteen years and upwards. Here we get the contrast; Germany, thirteen thousand, and the United Kingdom not quite four thousand; so the technical scholars in Germany are more than three times ss numerous as our own. At Massachussetts Institute of Technology, Boston, U.S.A, the number of students is 1,100, and the average age at entrance is 18½ years. This is in one school. It is certain that there are not to be found in all the technical schools in the United Kingdom, as many day scholars over eighteen years of age as can be found in either of the German or American institutions which I have named. Take next the teaching staff of these colleges, and it will be seen that in that respect also, we are far behind. Let us see how the engineering departments of three great technical schools stand. In the City and Guilds of London Technical College there are three professors, one assistant professor, and eighteen lecturers, etc., making a total of twenty-two. In the Massachussetts Institute of Technology, Boston, there are fourteen professors, twelve assistant professors, and 43 lecturers, etc., making a total of sixty-nine. In the Charlottenberg Technical High School, Berlin, there are twenty-four professors, twenty-two assistant professors, and forty-one lecturers, etc., making a total of eighty-seven. The number of students to each professor is as follows:—Berlin, 32; Boston, 21; London, 58. These figures speak for themselves! As I was informed by a former head of the Western University of Pennsylvania:—"When our men take a course in mechanical, civil, or mining engineering, they are required to don the habiliments of the shop and to daily perform a number of hours work in the shop, and they are required to learn the art of pattern making, of casting metal, of chipping and filing and planing, passing on to the making of miniature structural models to scale, representing proposed structures, such as railway bridges, the housing of a blast furnace. and various other kinds of machinery." So

it is plain that in the matter of technical instruction we have a great deal of leeway to make up before we catch our competitors in Germany and America.

MACHINERY.

Another point in which the Americans excel us is in the use of labour-saving machinery, a subject to which they are constantly paying attention, and with regard to which they are constantly developing new inventions. Some short-sighted people in this country are against labour-saving machinery, for the reason that it reduces the number of hands required, and therefore should be opposed. And on the same principle they think that the less time men work, and the less work they do, the more men will find employment. This is a theory firmly held by some even now. They seem to forget that the more you restrict the power of machinery, and the more you restrict the producing power of a man, either by the absence of proper machinery or by the ca-canny principle, the more you increase the cost of any article. And the more you increase the cost, you thereby lessen the demand, until you are pushed out of the market altogether by your enterprising and enlightened competitor, whether that competitor be in your own country or in America, or in Germany. The time has gone by when we can restrict production by these means and not suffer by it.

From the testimony we get from public and private sources, there is no doubt that the rule of "ca-canny" is practised very largely in this country, and it is generally certain that every man who practises it is doing an injury to himself, to his employer, and to his country. There is no doubt that the regulations of some trades unions in specifying the amount of work a man may do, is restrictive and binding to the last degree. It tends also to put the standard of production at the lowest scale and capacity of the poorest workman, and the best and sharpest workman is kept down to that standard, and is not allowed to earn more money by his superior ability to turn out more work. It is specified how much work he shall do, how many machines he shall attend to, how many rivets he shall put in for a day's work, who shall work alongside him in a shop, what kind of tools he shall use, and so on, thus giving very little scope for individual enterprise. How many days a week he shall work are also laid down. These are all restrictive methods. The American workman knows little or nothing of them. Each man is encouraged to do as much as he can, and he is paid by results.

Some of the men say that the great cause of England being in a backward position among the other nations of the world is the want of enterprise on the part of our manufacturers, in not introducing sufficient labour-saving appliances. But they must remember that before the master is induced to do this, he must feel sure of hearty co-operation on the part of his men, and he must feel satisfied that they will work harmoniously together for the attainment of this object. Now that

strikes me as one of the great wants of the English manufacturer—namely, perfect freedom between himself and his workmen to devise and carry out any plan for the cheapening of production, and the absence of any artificial rules which would interfere with or prevent that hearty co-operation which leads to economy. Let me give you an example of what I mean. I visited a large engineering establishment not very far from New York, where the forging department outran the capacity of the fitting department to take sufficiently fast what it produced. The consequence was that a great lot of forgings were always waiting for the fitting department to deal with, which caused a glut, and great inconvenience. The managers thereupon hit upon a plan of bonuses as applied to the fitters. The system was daywork ; a man was expected to do so much a day for his day's work and he did it; and then he was given bonuses in proportion to the amount of extra work he could do. The result may be expressed as follows. Take the unit of production of the ordinary day's work before the bonus as 1. After the bonus system was introduced the productive capacity of the fitting department went steadily up from 1 to 1¼, then 1½, then 1¾, and then 2, until in about twelve or eighteen months it went up to 2¼ times as much work as was done at the time when there was no bonus. It was optional with the men whether they accepted the bonus system or not, but I was told that this system was gradually spreading throughout the works, and would in time become general. Both men and masters were satisfied with the adoption of this principle. The men do not believe in restrictions being put upon their power to earn money, and they are more comfortable, more contented, and earn far more money by having freedom than if they were under the restrictive laws of the unions. So they told me over and over again. I was told by Americans that the great cause why they were so much ahead of us was that the men controlled the situation in England, whereas in America there was nothing of the kind, and both masters and men strove together to see how much they could produce for a day's work.

One American, a superintendent of a large steel works at Pittsburgh, told me that an English ironmaster was going over an American works sometime ago, when his attention was called to a labour-saving machine. He went home and tried to adopt it in his works. The process referred to was taking 24 men to perform in England, but in America it was taking only two men. The Englishman called his men together and asked them how many men they could dispense with if they had the American machine. They consulted together and came and told him that they thought they might manage with two less. So you see that meant 22 men in England against two men in America for the same work.

Mr. Schwab, the President of the American Steel Trust, has expressed his opinion on this point strongly. He says that the obstacle which we

have to overcome in this country is the great difference between English and American practice with regard to the unrestricted employment of labour-saving machinery. He also says that unless we are prepared to clear that obstacle out of the way we shall never occupy a position equal to that of America, with regard to facility of production. But I believe that enlightened English workmen are beginning to see the folly of this course of procedure, and there is no doubt they are adapting themselves with more readiness to labour-saving appliances. There is a great amount of prejudice still to be met, but when it is overcome, it will give the enterprising and intelligent British workman a far better chance than he has ever had. It will tend to stir up the lazy and incompetent, and will give such an impetus to British trade as it never has had, and will enable us to compete on more equal terms with our American and German rivals. This is sometimes denied in official utterances on the men's behalf; but go about in industrial workshops of this country and you will find it exists to a far greater extent than you have any idea of. In some shops in England, the principle adopted is to keep men back from learning really lucrative jobs too soon. The Uuions try to keep a kind of close corporation in some classes of employment and so keep really enterprising young men back.

Machinery is not everything. What is required also is the hearty co-operation of men and masters; freedom of contract between them, so to enable us to show what we really can do in the way of production over here. Until that day dawns, we cannot hope to compete on equal terms with other countries. If we can eliminate this restrictive policy, from the winning of the coal right up to the production of the finished article, we shall have made a great step in advance. I have been assured by English manufacturers who have gone over to America and seen men working, that they will produce 50 per cent. more work in America than they will in England with the same tools. Every man there seems to have an ambition to get on and to succeed in life and build himself a house or own one, and have that house as comfortable as he possibly can.

The next matter that I wish to touch upon is a wide one, namely, the national resources of America. These are vast, indeed almost illimitable. As far as the productive power of America is concerned, and the immense quantities of material she is able to produce, she will always be far ahead of us, or of perhaps any country, and this will enable her to supply the markets of the world, when she wishes to, in such a way as we cannot hope to do. Still we must remember that we are not handicapped by having to bring raw material such vast distances as the Americans. For instance, the Pittsburg people have to bring their ore 1,000 to 1,200 miles—a far greater distance than we have to bring most of our ore in England. A great many blast furnaces in England have the ore lying close to them. If you take the case of furnaces which

have to procure ore from Spain, or Norway, even then the distance is not so great as the Pittsburg manufacturers have to fetch their ore, which has to come 900 or 1,000 miles by water on the lakes, and 100 to 150 miles by rail. But such is the wonderful facility with which they get the ore by steam shovels, the ease and rapidity with which they load and unload the vessels, and low rates on the railways, the large cars, carrying 40 tons of ore at a time, the rapidity with which these cars are loaded and unloaded, that they can deliver ore to Pittsburg at a very cheap rate. They have coal, good coal, uear Pitsburg at from 1 to 1¼ dollars per ton (4s. to 5s.) Good coke, not far away, can be delivered to Pittsburg at from 2 dollars to 2½ dollars per ton (8s. to 10s.) And natural gas is obtainable at a price which comes out equal to about 5s. per ton of the price of coal. This natural gas is used to an enormous extent in Pittsburg, not only because of the low price, but it is cleaner than coal, it is easily controlled in the furnaces, and is of great heating power; so that there is no doubt it is a very great acquisition to the Pittsburg manufacturers. If our Mond gas, which we are to have in Staffordshire, equals this in price and quality, it will be a great boon to this district. Meanwhile, we wait in hope.

There is another question which, in seeking for reasons to account for the American problem, I must somewhat reluctantly mention, and that is the drinking habit. From my own observation, and from the inquiries I made, it is clear that it is far less evident over there than it is in our country. Whether it is a question of climate, or of superior education on the part of the men, I don't know, but certain it is that you do not find drinking prevalent in America to the same extent it is with us. In the first place the men take greater care of their money, and in the next place intemperance is not allowed in the works. If men come to their work the worse for beer they are sent to the right-about at once at a moment's notice, and there are plenty of men who are glad to step into their places. I venture to say there is scarcely a coal or ironmaster in the South Staffordshire district who has not suffered more or less severely from this habit among his men. Outsiders may think it is an easy matter to deal with, but it is a real and serious difficulty in some works, and hinders progress both in quality and quantity. Some men get the idea that if they have a good week or a good fortnight they must have time to spend the money, and that they cnnnot work without drink. But this is a most fallacious and should be, by this time, an exploded idea. I am far from saying that sobriety is uncommon among English workmen. It is not, and I believe the number of sober, steady, industrious, and saving British workmen is increasing, and there is no better workman than a man of that type. But everyone will admit there is great room for improvement yet. May that improvement still go on.

MANAGERS.

I should next like to offer some observations upon the important

subject of managers. I was very much struck with the class of managers they have in the works in America. They were mostly young men of 25 to 35 years of age. For the most part they were men who had had a good education in a High School, or a Technical College, or University, with scientific and practical training. After this, they come into a works at, say, 20 or 21, then they had several years practical experience as assistant to a manager, and finally they had developed into managers and superintendents at a very early age. They were mostly young men full of zeal, full of the power for work, full of a desire to get on, possessing any amount of that ambition which every young American seems to have, with a sharp, keen, alert mind, fruitful of ideas and initiative. The natural consequence is that they get on, and young men take positions there and undertake large responsibilities which makes one almost aghast. We have not a race of managers like that; but, with the spread of education, technical institutes, and, above all, a desire for self-improvement, there is no reason why in the near future we should not have a similar class. I have seen young men of twenty-five to thirty-five head superintendents of large steel and blast furnace plants. In this country we should think age and long experience the only qualifications.

RAILWAY RATES.

With regard to railway rates, not only rates but the management and facilities for dealing with traffic are much more in favour of the American trader than is the case here. Take the cost, for instance, of carrying ore 156 miles for 40 cents (1s. 8d.) a ton; sheets, bars, and billets from Pittsburg to Liverpool, 400 miles by rail and 3,000 miles by water, for 15s. to 16s. a ton the whole distance; and finished sheets from Pittsburg to New York, 450 miles, for three dollars (12s.) a ton. It costs us 10s. to 15s. a ton to deliver sheets to London, a distance of 115 miles, and 12s. 6d. a ton to send to Hull, and 17s. 6d. a ton to send to Glasgow, a distance of 280 miles.

Their mode of carrying traffic is far superior to ours. We think it a good sized train which carries 200 to 300 tons, but the Americans can carry in one train, with one engine, 2,000 to 2,500 tons. We think it a fairly large truck to carry ten tons of material; they think nothing of carrying forty and fifty tons in one truck. The American Pressed Steel Car Company, who are turning out 120 cars a week, are making nearly all their trucks of this carrying capacity They are all bogey trucks, and have no difficulties with curves. Their dead weight in a train is about 30 per cent, or a little over, whilst ours in England is about 50 per cent. Not only is this so, but the rates are not so fixed as with us. If trade is bad in America the rates are adapted to the condition of things.

Water carriage is very largely used on the lakes and on the rivers, and in places where the necessary canals are being constructed in con-

nection with the lakes and rivers. The Canadian iron and steel trades are proceeding in this direction and will soon be able, by this means, to get ore to the east coast of Canada at greatly reduced charges. Not only so, but the States are connecting their canals where possible with the great lakes and rivers, to enable them to carry merchandise by water all over the States. This is a point again in which we are slow to recognise our possibilities in England; other countries, such as Germany, France, and Belgium, are waking up to the importance of canals, and are spending millions of money in their construction and development. France has spent something like twenty millions of money on her canals in recent years. We have a canal system here, old and somewhat antiquated it is true, but capable of very great improvement and benefit to the trading community. If we had a good canal system, with improved canals capable of taking much larger boats than they do now, and instead of being drawn by the slow and tedious methods of horse traction, they were propelled by electric power, and further, supposing these canals were outside railway control and absolutely free to make their own arrangements, or to be arranged with by public bodies; then it would be to the interest of the railway companies to develop traffic on canals, seeing the enormous and ever-increasing amount of traffic the companies have to deal with. Sometimes the glut is so great that they are not capable of dealing with it. Such a freeing of the canals would also have a tendency to keep alive the trade in the inland districts which the railway companies are so dependent upon. Suppose we had a system such as I have indicated, and reaching, as new, to Liverpool, Manchester, London, and the Severn, it would not take, as it sometimes does at present, a week to reach London, or three or four days to get to Liverpool. If this idea could be carried out, either by private enterprise, by municipalities, or by the Government, it would be a splendid thing for trade. At any rate, our Government might give the same support and assistance in carrying through the House any scheme to accomplish this great enterprise as foreign Governments have done. Then the benefit to the great Midland districts would be immense, in fact, the advantage to the whole of central England would be incalculable, and the much-talked of time when these districts will be crushed out by competition at the coast will be indefinitely delayed, or perhaps averted altogether. But here again we move slowly, for we are met by vested interests, and therefore cannot progress. If only a strong public opinion were to arise demanding some relief in this direction, something might be done. It is always talked of as the necessary thing, the desirable thing; but at present, through various hindrances, it is impossible to bring it to a successful issue. We want a cheap inlet and outlet for our goods, then we can live.

TRUSTS.

I come now to a subject which I think is of general interest, namely, the question of trusts. There is no doubt this is the age of trnsts, both

in America and England, especially America. A trust, as Mr. Schwab says, is not like the old iron and steel associations previously established in England, or America, for the purpose of the restriction of out-put and the fixing of prices, with its costly management and more or less inefficient safeguards. But a trust is an association with one capital, one management, one policy, one control, co-ordinating all the different classes and stages of production into one united whole, and embracing in its operation transit by land and sea, the possession of steamers, of railway plant and railway lines, and the whole system of production from start to finish. Nor is it intended primarily for the purpose of restricting output, or putting up prices by artificial means, but mainly for the purpose of increasing production and cheapening cost. Well, there is no doubt it has that effect. Instead of the profits going into half a dozen or a dozen different hands, it all goes in one direction, namely, that of the trust. It simplifies management and agencies. It increases the output of works by giving them just that material to produce for which they are best suited. It economises capital charges, and it tends to prevent booms in one section or another of the productive departments; it also enables the trust to get its raw material at a regular and a reasonable rate. It also prevents undue competition between a number of small firms, all competing for business—that is if the trust is large enough and all embracing enough. But, of course, trusts have their difficulties and will have them. No trust can monopolise all the sources of supply or all the trade in a country. Monopolies last for a time, but by the influence of new discoveries and new departures, and the unconquerable tendencies of individual enterprise they are sure to be interfered w i more or less. They are also apt to suffer, especially in America, from over capitalisation, and from being what they are inclined to be, namely, a one-man company. They are pushed along and controlled by the commanding genius and personality of one man, and if a succession of such men cannot be found it is likely to go rather hard with the trust. However, they are a feature of the day in which we live, they have "caught on," as the Americans say. They seem to have come to stay. and we must make the best of them. They have a better chance in protected countries than in those which are unprotected. There is no doubt they have many advantages, and we can only applaud the energy of men in England who are determined that they will not be beaten by American competition But with our free and open ports, these progressive Englishmen have a more difficult task than the Americans, and we all hope, I am sure, that they will succeed in such enterprises.

With regard to American practice in blast furnaces and mills, the one point to which the American always, and on every possible occasion turns his attention, is to the question of labour-saving appliances. If his works are not alongside a river, or canal, or lake, he will have railway sidings always into his works, and in such a manner as to serve every department of the works in the most economical way possible. Then,

in every shop, great or small, where weighty goods have to be moved, there are in America overhead travelling cranes. That is the first and chief consideration—the overhead electric travelling crane. In one shop alone I saw seven 75-ton electric travellers. Large pieces of marine machinery, railway cars, locomotives, and immense castings of all kinds, are moved about as though they were toys. Electric and hydraulic installations form a very important feature in all American works. The speed at which their lathes go, and the depth of cut they take is a revelation. The perfect order and system observed in American works is another notable feature. The system of returns, and results of work in different departments, either in mills or in engineering shops, is carried out with a completeness aud a correctness which leaves nothing to be desired. The department of statistics and costs is worked up to a high degree of efficiency, and in a well managed works it is marvellous to see the celerity with which they can put their finger upon each different department and know all about it. The stoppage for breakages, re-turning of rolls, and replacing machinery is reduced to a minimum by the excellent system which the Americans adopt. No doubt we have shops in this country which are quite equal to the American shops in mechanical appliances, but they are the exception and not the rule.

We have heard a great deal about the scrapping of obsolete machinery in America. Well, this is a fact, it is carried to a large extent. If you visit a works now, for instance, and go again in twelve months or two years' time, you will find things altogether altered, you will find new methods and new ideas in operation, and the change often takes place with a quickness which is phenomenal. I heard of one American steel works which was said to have been practically re-built three times over in fifteen years. The English manufacturer says, and says truly, "Well, we have not the profits here which enable us to scrap machinery in this manner, so we must go on as best we can." That is perfectly true within certain limits. We have not the enormous profits of the Americans which enable them to spend scores and hundreds of thousands of pounds in the perfecting and replacement of machinery. The protective system of the American tariff, combined with the enormous domestic consumption of America, gives them that advantage. Of course, the community as a whole have to pay for this protective system, but they do not mind so much when they earn plenty of money themselves to enable them to pay the prices brought about by the protective system.

But whilst we cannot spend money so freely on works as they do, still, we must not forget the necessity of doing it if we are at all to keep alongside in the race. And it is being done, I am glad to say, more than ever, perhaps, according to our opportunities.

The production of furnaces and mills is truly collosal in America. What do we English ironmasters think of a production of 751 tons in

24 hours by a blast furnace (Edgar Thompson), or of a production of 4,700 tons in one week out of one furnace? That is the rate at which the furnaces are being worked in America, and I hear that is even being exceeded now. Or what do we think of one furnace making 1,000,000 tons of iron before it is blown out for repairs or re-lining. What should we think of a production of 250 tons of half-inch round steel in 24 hours, out of 2 inch billets 30 feet long, or of a production of 500 tons in a day of 24 hours, of 1¼ inch to 2 inch rounds out of a 5 inch billet? Yet this is being done in a Morgan continuous mill in the Pittsburg district, continuous charging and drawing going on in a specially designed furnace, worked automatically. In the heating of steel, gas furnaces of one or another kind are exclusively used, and as I have said before, in many cases the fuel is natural gas. I have not time to go into details, but no doubt you have heard of the Morgan continuous mills, and the continuous charging furnaces.

PROTECTION.

There is one question to which I must certainly refer before concluding this address, and that is the subject of Protection. Some people imagine it is the one sovereign remedy for all our troubles in England, and that if we had Protection for our industries, everything would come right. I do not entertain this view. I believe there are other items in the general cost of production upon which we have to fix our attention, and I believe also we shall have to do this increasingly if we are to maintain our ground. But at the same time, I am far from saying it is not a factor in the problem for which we are seeking to find a solution.

We are the one great commercial nation in the world which keeps resolutely to Free Trade, while other countries, both old and new, are steadily and persistently going in the contrary direction. There are many who hold that the theory of Free Trade is right; yet there is no denying that this doctrine has been before the world for 50 years and yet we do not find any imitators. One would have thought that if it were a good thing for us it would be a good thing also for other countries, and that our own example would have been followed. Either they are wise and we are unwise, or *vice versa*. There is no doubt we have had an unprecedented period of prosperity during the last half of the last century; but is that attributable only to Free Trade? If so, how is it that other countries have also prospered by adopting Protection, and not only adopting it, but by even increasing the imposts from time to time? Of coure it may be said that the conditions are not the same in this country as in the case of others who adopt Protection. They may not be the same; but are they such as to warrant the wholesale flooding of our markets with materials which we ought to produce ourselves, if we could manufacture them in sufficient quantity and cheapness? Take for instance the value of our total imports of iron and steel for the last few years. In 1890 they were 385,660 tons; in 1896

they were 459,554 tons; in 1898 they were 591,431 tons; in 1900 they were 799,674 tons; and in 1901 they were 924,000 tons. The value of last year's imports was £6,300,000. Since 1895 our imports of iron and steel have just doubled.

In the last seven years we have imported 4,200,000 tons of iron and steel. If we take the imports of iron and steel for 1901, namely, 924,000 tons, of the value of £6,300,000, and if we include machinery, which was of the value ot about £4,000,oco, then we get an aggregate of £10,300,000. Surely that is sufficient to make our manufacturers look round.

Our production of pigs is going down here at the same time. Why cannot we make all this iron and steel ourselves? Either it is the fault of our fiscal system or our methods are antiquated. But, look at the employment it means to produce nearly 1,000,000 tons of iron and steel and £4,000,000 worth of machinery.

It may benefit some traders to be able to buy cheap, foreign, iron and steel, especially if in the raw state, or semi-manufactured state. But it injures others when it comes in the shape of the finished article, and it throws our workmen out of employment.

"Made in Germany" has almost ceased to be a word of opprobrium, and in some cases it has become a recommendation; but while Germany is increasingly flooding this country with her productions, such as iron and steel goods (both raw and manufactured), nails, wire, screws, clothing furniture, pens, and almost every conceivable article, she is raising a higher wall of protection against the productions of other countries It is said we buy cheap German raw material so that we may re-manufacture and export abroad at a cheap rate; but we buy a great deal which is not re-exported, and the question is, how far are we neglecting our home markets, which are enormous, through our desire to manufacture cheaply to meet the export trade. The iron trade is not the only trade feeling this competition. Lord Masham has lately been deploring the same tendency of increased imports and decreased exports, especially in the case of velvets, silks, etc How far the patriotic resolve of Her Majesty in purchasing only English made goods of this class, will affect the buying community, is very doubtful.

Then our best and largest industry, the one which should be the largest customer for the products of this country, is declining and dwindling in a remarkable manner. I refer to agriculture.

I say again I am not laying down a dogma. I am not denouncing or condemning free trade, and what it has done; but what I want to ask is—are the conditions of this country changing, and how can we decide whether our inability to meet foreign competition is due to our supineness and want of activity and brains, or how far is it due to our fiscal system? At any rate, this ought to be made a subject of earnest

inquiry before all our staple trades are knocked on the head. For we are assured on all hands that the competition we suffer from now is nothing to what we may expect in the future.

And we are told that America is so increasing her productive power that the time is coming when she will far outgrow her own power of consumption, though at present she does not do so. And then we must look out for a still further flooding of our markets. America will then be open to make arrangements of a reciprocal nature with those countries, who insist on a *quid pro quo;* but those who are unalterably fixed to free trade must expect no consideration at her hands. At any rate, whatever we may do with foreign countries, we may, and ought to try to draw closer the bonds of a mutual trade with our colonies. And it is to be hoped that the unity of hearts which now exists in such a remarkable degree between the colonies and the mother country may be drawn still closer, that any trade barriers which exist may be done away with. This disposition exists in Canada, and in New Zealand. Mr. Seddon, Premier, has publicly stated that the colonies are ripe for a preferential tariff. He said that it was pleasing to note that the Imperial authorities had intimated that they would not stand the bounty system much longer. The most effective way, and one which would cause least irritation, would be for the colonies and New Zealand to grant a rebate, or drawback, on all British manufactured goods brought into the colonies by British ships, the Imperial authorities granting a similar rebate on colonial products upon which duties were now chargeable.

The enormous extent of the field for British trade which is opening up in Canada must be patent to all observers. Lord Strathcona, the High Commissioner for Canada, in the course of a letter appearing in the *Daily Telegraph,* directs attention to the last year's trade figures, showing a large increase in Canadian exports and imports. An analysis of the figures, he says, indicates that the export trade of the United Kingdom with Canada is expanding under the preferential tariff, and that the natural products and manufactures of Canada are being imported in largely increasing quantities into the United Kingdom. Satisfactory as the figures are, however, says Lord Strathcona, the United Kingdom will no doubt secure a larger share of the import trade of Canada; and on the other hand, the imports into the United Kingdom from Canada form a very small percentage of the requirements of the country, and are capable of much expansion. Canada is anxious to develop inter-Imperial trade. Nothing would give Canadians greater satisfaction than a further increase in British imports. He is convinced that much could be done to bring about this result by the wider dissemination of knowledge of the products of Canada, and, as High Commissioner, he invites correspondence on all matters likely to improve Canadian export trade or to help to develop British exports to the Dominion.

It must be clearly understood that we must not depend upon protection to bolster up any antiquated methods and place it in lieu of vigilance and ability on our part, but I simply mention it as one feature in the very complex problem which we have before us at the present time. This address deals more with the outlines of this great subject of foreign competition, and does not go into details, as this would necessarily be impossible with the time at my disposal; but I think I have said enough to indicate the lines upon which improvement may be made. They are:—

1. Better education, primary, secondary, technical.
2. Labour-saving machinery.
3. Payment by results.
4. Better understanding, and greater freedom and co-operation between masters and men.
5. Sobriety.
6. Better trained managers.
7. Greater push and hard work on the part of the masters.
8. Railway rates and railway management.
9. Improvement of our canals and waterways.
10. Trusts.
11. Practice improved in our blast furnaces and mills, especially by the introduction of electricity.
12. Protection.
13. Closer trading relations with our colonies.

This is a sufficiently wide range of subjects to think about, but I am convinced that they all have a bearing on the great and important subject that we have under discussion. None of these matters must be neglected if we are to hold our own; and if it is necessary for the public in this country to wake up, and for the Government to do so, in so far as it can help, then it is equally also your duty and mine to demand that attention be called to these matters while we have time, and it is our duty to see that we do not drift along under the idea that "all is for the best," and that all we have to do is to "leave things alone." The Americans say they are determined to fight us at home and in the colonies, and they have an idea that we cannot stand against them when they want to compete with us. It remains to be seen what the result will be; but I shall refuse to believe that dogged British pluck and endurance, and our inventive power, will be beaten out of the field. But we need to look at the matter well. It is not one point, it is many which require looking into. The subject is many sided, and do not let us make the mistake of supposing that there is one, and one

only, remedy for the condition of things. We must wake up all round—masters, managers, and men, to the gravity of the situation. I make these remarks in all good feeling, out of a sincere desire to advance the interest of our country as a trading country, and especially of the Midland districts.

THE DISCUSSION.

Mr. H. Le Neve Foster: I am sure we have all listened with great interest to Mr. Parkes's address, and thoroughly appreciated his presence among us. Mr. Parkes has told us that we must wake up if we want to retain the supremacy of the British iron and steel trades in the future. Staffordshire, especially, will have to wake up. At the present time we have a number of comparatively small iron works, and it is impossible for them to manufacture steel on their own account cheaply. Therefore, what is wanted in this district is a steel works which will produce steel in a partly finished state, to take the place of puddled bars, for these small works to finish themselves. At the present time, as most of you are aware, we have only two or three works in this district which make steel, but they finish it completely. What is required is a large central works which will make steel billets on the most economical principles; this steel can then be delivered to the smaller works and they can finish it themselves. With regard to allegations about South Staffordshire being played out, I do not think that we have come to the end of our tether yet, and I think that eventually we shall be able to deal satisfactorily even with American competition. At the present time, what I understand is the largest Talbot steel furnace in existence is being worked in this country, at Frodingham. This is a 100-ton furnace, and it is even larger than any furnace in America. I see Mr. Parkes is shaking his head, but I think it is correct. There are several more of these furnaces to be erected by Guest, Keen, and Co., and I believe the capacity of these is from 150 to 200 tons, so that even in the steel world we shall soon be able to compete with America in the matter of large furnaces. The whole question of trade competition illustrates the law of the survival af the fittest. It is a question of machinery, and we shall have to adopt the best and latest machinery if our works are to survive, and I believe that we shall survive.

Mr. Herbert Pilkington: I have listened to Mr. Parkes's address with a considerable amount of pleasure inasmuch as it is not very long ago since I went over to America and saw most of, if not more than what he saw there. I can confirm much of what he has said, because, in addition to going to Pittsburg I went to a district even more dangerous to us

than Pittsburg. I went down into Tennessee and Alabama, where they have plenty of cheap negro labour, and where they can see their coal and iron ore mines and limestone pits from the tops of their furnaces, so that they have plenty of materials of every class within easy reach. They can, indeed, produce pig iron at 20s. a ton, and deliver it to the nearest ports for another 4s. Since my visit, some of the Tennessee people have put down steel works, and they are now proposing to export finished material instead of pig iron to this country, and before long the competition from the Gulf of Mexico will be even greater than what we have experienced from the Carnegie Works of the American Steel Trust, simply because the cost of production and transit are so very much less than in the Pittsburg district. I agree with Mr. Parkes in his remarks about managers and men. There is no doubt that both the managers and men want very much improvement in this country. It is a very awkward thing for an Englishman to stand up and palpably admit that there is any country in which those of his class are better than he. I feel this, but I feel also that what I say is nevertheless true. I don't think, however, that very much point has been made of the real kernel of the whole matter. How is it that managers and men are what they are? They are as they have been made by the capitalists, or by the boards of directors, or the owners who employ them. Now I wish to use that argument with all due respect, I think we have all got to pull together to get out of the mess we are now in with regard to foreign competition. The day has arrived when we should consider what the requirements of the times are among owners of works, among boards of directors, among the financial men who have the supreme control over our works. The time for ornamental directors has gone. The time for guinea pigs has gone also. The time has arrived when those who are in supreme control over our great iron and steel works shall be men who have some real connection with what they are supposed to do. They ought to be men of real financial and engineering or commercial abilities, capable of considering the fact that men and managers have to be trained, and capable of understanding their people's experiences in the works and their difficulties. I am speaking now of what I have often thought for many years. As a manager who has gone through a considerable amount of experience, I have often noted the lack of interest which those people in supreme control have exercised with regard to the training of their future managers and men. Is it not a fact, well known to most of you here, that there has been a lack of interest in the upbringing of men who are to take the future control of the works which we are managing now? There is also another point, and that is the policy which the men have been following for some time, known as the ca-canny (go-easy) policy, a policy with which I have had to contend, personally, for a long while. Trade Unions are all very well in a way, and in some senses they have done very much good in this country. They crystallise, in a certain sense, the opinion of

the men whom they represent, and they provide some definite authority, and some definite man, to deal with and to negotiate with, with regard to what they want. My own experience has been that the officials of these Unions have been better to deal with than certain advanced men belonging to their own party. These latter often cause very considerable trouble, as all extremists do. The Amalgamated Society of Engineers and the other older Unions have learned a great many things in the course of their experience, and they are not so troublesome in consequence of that experience, which has taught them natural limitations and business nous. But there are younger unions with which many of us have to deal, and which it is perhaps not wise to name; but some of these younger societies certainly have very much yet to learn with regard to the best method of conducting the business affairs of trade unions, and their members often cause a great deal of trouble to works' managers by their lack of knowledge and sometimes lack of honesty. All I have to say with regard to these unions is that they fail in selecting the proper men to look after their interests. A works' secretary, or a shop secretary, is often selected mainly because he can "spout," and not because he is a man with the shrewd commonsense possessed by those who do the right thing at the right time and in the right place. In some particular trades in America this period or phase of trades unionism has been fought through years ago. They do not obstruct or limit production, they have found the highway to high wages. They are as advanced as the owners, and they work together for the common good, and have now arrived at a point which may be considered almost perfect harmony. There is, however, another point which I should like to touch upon, and that is that in America we can give the employers credit for dealing fairly and squarely by their men For instance, when a piecework price is fixed, in America, and the man increases the production and makes big earnings for himself, the American employer gives it him without grumbling, whereas, in this country the employer would probably dock the rate. In America, so long as that particular job of piecework is in force the rate holds good. When any man introduces any idea, also, by which he makes a bigger amount on a piecework job, for himself, then he gets the full benefit of that kink or new idea which he introduces. The employer does not, as he does in this country, penalise the results of the ingenuity of the workman.

This general question of foreign competition is a topic which one might talk about all night. It is a subject which very much interests me, and I am sure the address we have heard to-night is one which we might very well think over at our leisure. I notice Mr. Parkes did not talk about the relation between Parliament and trade. I am not a politician. I gave it up years ago, for I found its connection with trade and industry remote and unprofitable, but I notice he did not mention the fact that America has no Factory Acts and no Compensation Acts, and many other

things which his party, and indeed public opinion, has been responsible for in England. That has something to do with the question of foreign competition. I should like, in conclusion, to say that I am afraid there is not much respect for human life in American iron and steel works. We have very much more respect for human life and human comfort, and for the ordinary conveniences for life than they have.

Mr. H. G. Mantle · I am not a member of this Iustitute, but as the President has called upon me to make a few remarks, I will do so. I came to hear what Mr. Parkes had to say, and I have been extremely gratified with all the observations he has made. He has raised numbers of points which will afford us abundant food for reflection, and if we only go to the trouble of carefully considering what he has said, we shall be able to evolve out of his paper some very solid reasons for our present trade depression I think that the most important point touched upon to-night is the question of protection. We have for some years past been improving our machinery and appliances. English ironmasters are not in the position that the American ironmasters are in. They have not command of so much capital, and cannot do things upon so large a scale; but we are all doing our best, and I can safely believe that the works at present existing in Great Britain are a very great improvement upon those of a few years ago; but even with our better education, and our improved machinery and appliances, the odds are agaiust us, and as long as this is so, I am rather afraid we shall do very little good in meeting American and German competition. It is in that direction that I certainly think we shall eventually have to look, and Mr. Parkes has to-night suggested that at all events the matter of a protective tariff is worthy of consideration, and I entirely agree with him. The position of America to-day is that her receipts vastly exceed her expenditure. The exports are greater than the imports. Her whole position is one of prosperity, while our receipts are unfortunately less than our expenditure, our exports being much lower than our imports. And as long as our purchases go on continually exceeding our sa'es, it is almost impossible for us to expect to live for any length of time. That is a most unhealthy state of things, and if America is in such a favourable condition as regards her natural resources and improved machinery, that is all the more reason why we ourselves, being evidently to some extent only a second-rate commercial power, ought to consider whether it is not advisable to impose countervailing duties in self defence. We have to live, and if we cannot make a profit out of our transactions we shall all very speedily go to the wall. But I hope the time is far distant when, as Macaulay said, some Australian might be seen sketching the ruins of St. Paul's. But unless we consider this question and look to our laurels, I am afraid that time is nearer than we expect. What is the good of our acquisition of colonies whilst the heart of the country is kept weak by excessive competition from Belgium and Germany and America. If

the root of the tree is unsound, all the branches of our great Empire will very speedily be lopped off. We must look to ourselves. I must apologise for having touched upon this subject, but I believe it is an important one, and will have to be taken up by our legislators before long, and I am, therefore, very glad to see that Mr. Parkes, whilst not committing himself to any very definite opinion, has yet suggested that the question is at least worthy of consideration.

Mr. Thomas Turner: It has been said by other speakers, and I am pleased to be able to say it again, that we are very much indebted to Mr. Parkes for coming among us, and we have shown by our numbers how much interest we take in the subject he has brought before us. Some of the members may have it in their recollection that some twelve years ago, or more, that I ventured in this building to give an account of the iron ores of America, and pointed out, in an address illustrated with a number of samples, how immense were its resources. The only wonder to those who have any knowledge of these resources is that American competition has not come sooner. It is only because they have not sufficiently developed their own country, that they can absorb their own material so completely, and in consequence we have not felt their competition more. It is the great question of the world—this question of American competition in manufactured products. I am, however, interested at the present time more in educational work, and I was therefore very pleased to hear what Mr. Parkes had to say about the necessity for the training of the managers in our works. Perhaps there is nothing more remarkable in going abroad, either in America or in Germany, than the type of men with whom you come in contact when you are taken round the works. You begin to talk to a man, generally a young man, and in a little while, such is the tenor of his conversation that you find yourself asking him what his college was, or the name of his university. But in our district the managers who occupy important positions are almost to be counted on two hands who are able to say that they have gone through a thoroughly good high-class institution, and have spent there three or four years. We think three years is a long time to spend in England, but the courses in America are generally four years instead of three. The fact is, our managers have been trained, as we now find, on the wrong principle. They are good old practical men, and they know the details of their work, and from some points of view they are not to be excelled. I see faces round me to-night of men who, for their practical knowledge could not possibly be excelled. Most of our managers have risen from the ranks, and have not had the advantages of scientific training. Now we hear a great deal about Army reform at the present time. I do not profess to know anything about military matters, but I believe there is one thing the army does well. They start by training one class of men to be privates; and then they train another class of men on an entirely different system, to be officers. Facilities are also provided whereby for

special services or fitness, men may rise from the ranks. Now we ought to adopt the same idea in commercial matters. If a man is to be a private give him a limited amount of education of a definitely useful character. But if he is to be an officer we want to give him a longer period of training, and that training must be of a special kind. Now this Institute has taken a great deal of interest in the proposals for the formation of the University of Birmingham, and we hope to have there a splendid school for technical education. The great thing we have to keep before us is the necessity for higher training. We have a good elementary educational system, and we have excellent evening classes under the Technical Instruction Act. But what we want is technical training in day schools or colleges, where young men of 17 or 18 may devote their whole time to preparing themselves to become managers, where they may come for three or four years to take up the matter seriously, and to thoroughly learn the responsible business of their future life.

Mr. Henry Parry: In common with other members, I have listened with very great pleasure to Mr. Parkes's address. I think there is one item which Mr. Parkes might have added to his list of obstacles in the way of British trade, and that is the House of Commons itself, of which he is a distinguished member. We are above all things a commercial nation. Gentlemen are sent up to the House of Commons to represent every interest, and we have sent from this district gentlemen like Mr. Parkes, Sir Benjamin Hingley, Sir Alfred Hickman, and others, who in their own business are unexcelled, to represent the iron and steel trades in particular. But how often do you hear of these gentlemen being permitted to express their views in the House of Commons? Mr. Parkes has been able to interest us for an hour and a half on the important subject he has taken up, but a very short paragraph would describe all the House of Commons would listen to. The fact is, the procedure of the House of Commons is such that he and other commercial representatives never get a chance of speaking on trade subjects. Therefore, I hold that if he wants to improve our trade, the first thing he ought to do is to set about reforming the methods of the House of Commons.

Mr. James Roberts: It was a capital suggestion of Mr. Parkes in the peroration of his speech, when he gave us a summary of the heads of the subject upon which he had been talking, and it occurred to me that it would be a very good thing for everybody in this Institute if it could be arranged that we could have a debate upon each of these heads, getting someone to start with a short paper and someone to open a debate on both sides, for there is plenty of matter in each one of these heads for a good discussion. Much has been said about education in general, and about the education of managers in particular. Well, it is a subject which was very dear to my heart during the time I was President of this Institute. But I have felt all along that the education for which we are paying vast sums in this country was not producing the results which it ought

to produce, that the continuity of the education was broken just where it ought to be carried on. Mr. Parkes has shown us what is being done in Germany and America. I have not been to the iron and steel works of America, but I do know something of the French and German works, and I can assure you that the men there who are in control of these works —works which are now in keenest competition with us— have had a far superior technical education to ourselves. It is nothing unusual to find that when you are talking to a forge manager you are talking to a doctor. I don't mean a doctor of medicine. Many of them have been educated at a University. Our works managers are practical men, and can tell you how to make iron and steel, and how to handle the steel when it is in the rolls. They are men who are difficult to beat in practical matters, but they lack the capability of appreciating the great benefits which hydraulic power and electricity are able to confer upon us in the economical production of the material which we have to use. There are many points in Mr. Parkes's speech with which I think I agree; one in particular is that the question of protection should be considered. Not that I wish to take an unfair advantage of anybody. The ordinary acceptation of the word protection, I am sure, is to give somebody something at the expense of somebody else. But that is not what we mean. The question has sometimes been referred to as a ring between our colonies and ourselves. I thoroughly believe that that will come about, and that it will be the best thing that can possibly happen for this country and for our colonies. They can supply us with everything we want if we will only take it from them, and we can supply them with all the manufactured articles they may require. I do not wish to make any definite pronouncement upon this great fiscal question, but it seems to me that we have a case to consider, and if we can do anything to meet these restrictive duties, then, perhaps, we shall not be over-run by German steel to the extent that we are at present; or, if we are, then, at any rate, they will have to pay something proportionate to what we have to pay when we send machinery to their country.

The President: What I said over 20 years ago I still think, namely, that we want a greater combination among masters, men, and managers. I have always believed in harmonious relations, and in the free exchange of ideas, and to-night we have yet another example of the usefulness of all getting together and giving each other the benefit of our opinions upon trade matters. With regard to our having a large steel works in the centre of South Staffordshire, I think the waterway right away from this district, North, West, East and South, of which I have spoken several times, must be the first thing, or the railway companies would soon eat up the profits of any new steel works by their charges. If we had water communication it would help us to compete favourably with America. I don't think for a moment but what we are ready to amend any shortcomings that may have been in the past, and I feel sure that the rising

young men in this Institute will be only too glad to take any advantage of the various facilities offered in this district, in order to fit themselves for the post of managers in this country, so as to be better able to meet foreign competition. There is one matter I should like to mention, and that is with regard to patents. There are many managers and men in works who have good ideas, but have no means of ventilating them. We want a special department attached to the Birmingham University where opportunity will be offered to such men, and invention encouraged. As you know, I have often complained in this room very bitterly about our furnaces in this district, and I feel that, like a great many others, I am behindhand with my furnaces at my own works. Now there are many men with ideas as to improvements in furnaces and in other plant, which ideas should, I think, come before a committee who could see if any one idea was worth taking up ; if so, the improvement should be tried, strictly in private, so that it should not go out to the world, and then if the invention proved feasible, some arrangement might be made whereby the man who brings the idea out should reap a benefit, and whereby also the University (or other body who take the matter up) should be recompensed for the trouble they have been put to. Such a system as that would encourage invention, and would make managers and others more interested that at present in assisting us to meet the competition of foreign countries.

Mr. EBENEZER PARKES, in replying to the debate, said: First, as to Mr. Foster's remarks. He suggested a new central steel works in Staffordshire. I think it would be a distinct advantage to have such a place, instead of having to import the steel from Wales, or Germany, or the North of England. But for an enterprise of that sort capital is needed, and people will not put their money into it unless there is confidence as to the future of trade. Certainly improved water communication would tend to increase that confidence. With regard to the Talbot furnace, I am exceedingly glad to find that we have one at Frodingham, and that others are to be put down in South Wales. I scarcely think, however, that the Frodingham one can be the biggest in existence, for if I remember rightly they were about putting down three or four 200-ton furnaces at one place in America when I was there. With regard to Mr. Pilkington's remarks about the Southern States, I also, went to Alabama, but I think he will agree with me that they are not nearly so advanced in their practice there as they are in the Pittsburg district. I admit that they have a greater advantage in the way of proximity to the coast, and the nearness of their raw materials to the producing works ; but as far as practice is concerned, and improvements, and mechanical ideas, they certainly are not ahead of Pittsburg. The place whence we may expect competition is Canada, for there they can produce even more cheaply than in Alabama. Mr. Pilkington touched also upon the Factory Acts and Compensation Acts. I myself am glad that we have a Compensation

Act in this country, for it is a good thing for the men. There is certainly not so much respect for life in America as there is in this country, especially for nigger life. But you cannot help being struck by the fact that the general condition, the bearing, the clothing, and the housing of the average American working man is superior there to what it is in this country. He works harder, and is a highly self-respecting man; but I don't think that the material of the working man (as apart from his environments) is any better in America than it is in England. A great number of men have gone over from this country and they often become leading men in American works. I found a great many English people there who had taken important positions in that country, and this shows that the stuff English working men are made of is the right stuff, and that it only wants leading into the right direction. Mr. Parry said I did not mention the House of Commons. That is a mistake, for I mentioned Government and its power of influencing trade a time or two in my address. I think there are departments of trade in this country which really do want the assistance of a powerful Government such as we now have. Why you don't hear men connected with trade speak about trade matters in the House of Commons is because trade questions form a very unimportant part of the deliberations of that august assembly. Then again, trade matters are often relegated to the Grand Committee on trade, and that is a committee upon which I have served for several years, and of that committee the general public know very little indeed, and although, as Mr. Parry says, my voice may not have been heard very often in the House of Commons, yet, I am glad to say, it is heard pretty often on the Committee of Trade. I am very pleased to have had an opportunity of coming amongst you to-night, and of addressing a body composed of managers as well as employers, of members from a distance like Mr. Pilkington, and also of scientists like Mr. Turner. My only object is to try to arouse interest in the minds of all of you in this part of the country, because I feel that this question of foreign competition is really a question of life or death to us. And if I have caused some of you to wish to become possessed of American push and assiduity, my purpose will have been fulfilled.

A vote of thanks to Mr. Parkes was proposed by Mr. J. W. Hall, who referred to the comprehensiveness and the utility of the address, and observed that the appreciation of the members was amply shown by the fact that the announcement that Mr. Parkes was to address them, had drawn together one of the largest attendances of members he had ever known.

Mr. W. Brooks, who seconded the vote of thanks, said he believed Mr. Parkes had given them all food for reflection. With regard to some Americans getting 50 per cent. more work out of a machine than Englishmen, he thought that reflected quite as much upon the employer as upon the men. What a pity Mr. Somers did not import workmen from

America to work his lathes. Doubtless he would then get his crankshafts done in half the time, and everything else done at double quick speed. But he (Mr. Brooks) could not say that his own experience was in favour of American workmen. He had engaged a man a few days ago who had just come from America, but up to the present that man was a good deal behind, and had not been able to anything like reach the English standard. A great deal had been said about management, but it was not technical education only that would enable a man to hold a position as manager. If that was to be done he must be a good all-round man, and have many good qualities. Even well educated managers were not always able to get their best work out of the men; to get it out of another man, he must have been a workman himself.

The motion was then put and carried with long applause.

Mr. MANTLE: I should like to ask Mr. Parkes if there is any likelihood of countervailing duties being discussed at an early date in the House of Commons, and if so what attitude he would take up with regard to it.

Mr. PARKES: I am afraid there is no immediate prospect, but I shall continue to give the matter my best attention. With regard to what our friend has just said about the American workman, there are, of course, good and bad workmen in America, as in every other country. He must have got hold of one of the poor specimens. I find a great deal of incredulity among English people with regard to what America can accomplish, and in such cases I can only recommend them to go over there and see for themselves.

The proceedings then terminated.

The sixth Meeting of the Session was held at The Institute, Dudley, on Saturday, February 15th, 1902.

In the absence of the President through indisposition, Mr. W. Yeomans was voted Chairman.

The minutes of the previous meeting were read, adopted, and signed.

Mr. Ernest J. Whitehouse, of the Phœnix Iron Foundry, Tipton, was elected a member of the Institute.

The Chairman then introduced Mr. S. J. Thompson, who read the following paper:—

THE DÜRR WATER-TUBE BOILER.

By S. J. THOMPSON.

The water-tube boiler question has been very prominent before the engineering public during the last few years, but the discussions have to a very large extent dealt with the Marine type from the Admiralty point of view, and while I propose later to illustrate the Dürr Marine Boiler (twenty of which are now being tried by our Admiralty), it is more particularly the Land type of boiler to which I wish to draw your attention.

The past history of land boilers is most interesting; every conceivable design and construction seems to have been tried. Broadly, they may be divided into three main divisions :—(1) Externally-fired Cylindrical Boilers. (2) Internally-fired Tube Boilers. (3) Water-tube Boilers; and they have been used for steam-raising in about the same order in this country. Cylindrical boilers are now almost things of the past. Lancashires are the boilers of the present, and while still holding their own, yet the still increasing demand for a boiler fulfilling the conditions of great pressure with safety, quick steam raising, large heating surface in small space, along with economical results, points to the Water-tube as the boiler of the future.

Electric installations are springing up all around us, and the Water-tube boiler is the type usually adopted. My firm decided some two years ago to manufacture a boiler to meet this demand, and at first proposed to design one to fulfil these conditions, but while it is comparatively easy to design a patent boiler the building and experimenting with it takes years, and after all might not prove a success. Eventually, we decided to take up a Water-tube boiler that had been exhaustively tried and had long passed the experimental stage. We were unbiassed and unpledged to any type, so free to choose from the large field of Patent Water-tube boilers. After carefully inspecting, and seeing numerous types under work, in America, on the Continent, and in this country, we at length found that the Dürr Boiler came nearest to our ideal of what a Water-tube boiler should be, so some twelve months ago we bought the patents for the United Kingdom and Colonies, of the Dürr Boiler (Land Type).

Our opinion as to its merits has since been confirmed, first by the Admiralty Boiler Commission, composed of experts, who six months ago, recommended the Dürr among the few others as satisfactory to replace the Belville; and recently by The Fairfield Ship Building Co., Ltd., who have bought the rights of manufacturing the Marine type.

In discussing boilers, it is as well to say at the outset, that no particular type of boiler can in all respects be said to be superior to every other, and the advantages and disadvantages of any type must be carefully weighed according to the conditions under which they are worked.

I propose to divide this paper into different sections:—(1)

THE SIMPLE CONSTRUCTION OF THE DÜRR BOILER.

This boiler is of the large straight tube type, and composed of three main elements. (1) Upper drums, (2) header (common to all tubes), and (3) Dürr tubes (see plate 1).

Drums.—For small boilers one drum only is necessary, but the larger sizes have two, the length varying according to the space at disposal, usually 22ft. 6in. long, and from 3ft. to 4ft. 6in., diameter. We make a special point of large steam and water drums, so that there may be a reserve of power, having found that small drums are often the cause of priming.

Plate 1 shows an outline drawing for one of six boilers now under construction. The general particulars are two drums, each 22ft. 6in. long by 3ft. 6in. internal diameter, having 96 4½in. tubes, and constructed for a daily working pressure of 200lbs. per square inch; each of these boilers is capable of evaporating 7,000 to 8,000 lbs. per hour under ordinary conditions, having 2,100 square feet of heating surface, and 45 square feet of grate area.

These drums are connected for circulation purposes by a saddle-piece, A, oval holes being cut at top and bottom to maintain equal water level and pressure. The dome is fitted upon the drum in which the feed does not enter. The welded header is flanged and double rivetted to the drums, oblong holes the full width of the neck having been cut out to allow for the efficient circulation of the steam and water.

It will be noticed that they are in three plates only, circular seams double rivetted, longitudinal seams butted, and the ends well flanged and dished (by hydraulic).

The Header.—The Dürr Boiler differs from the usual type of water-tube boilers in this respect, that it has one header only connected to the drums at the front end, which is common to all tubes. From a constructional point of view this is a great advantage over the staggered sectional headers both at front and back ends, as it does away with a number of objectionable joints.

The welded header is of mild steel throughout, and is composed of two plates only; the rear tube plate being flanged to form the bottom and sides of header, also the saddle-piece for connecting to drums; the front plate is then welded on, making a strong chamber without laps or rivets.

There are mild steel 1¼in. screwed stays at suitable centres of the header to effectually withstand the pressure.

Partition Plate.—A little out of centre, so as to allow efficient circulation of the water, a partition plate ¼in. thick is fitted, having holes bored concentric with the tube holes, of a slightly larger size for the removal of the tubes. It is held in position by the screwed stays which are tapped through the three plates at the same time, holding it firmly in place.

Holes —Large holes are bored in the rear tube plate as well as in the front for the lids opposite each tube, these are afterwards milled to a standard size, the holes being tapered to make the Dürr patent metal to metal joint.

Dürr Tubes.—These tubes are always of the large straight type, 4in. to 4½in. diameter, and from 16ft. to 18ft. 3in long, according to space at disposal, and are placed in a zig-zag manner that the gases may impinge upon their surfaces. The two bottom rows are thicker that the remaining upper ones on account of the fierce heat from the fire. It will be noticed that they fall towards the back end, this being allowed for by the header being placed in a sloping position towards the front.

The chief feature is their attachment to one end only, which enables the tubes to expand freely without fear of leakage or bending.

Plate 1, fig. 2, shows the unique method of fastening. The outer tube A being thickened up or having a collar welded on at the front end on the outer side, which is then turned to a standard taper gauge ; this cone is of sufficient length to allow for any slight differences, and a small outside rim prevents any possibility of the tube being forced through the tube plate. A special grease is rubbed on the surfaces to prevent corrosion, and the tube is then pressed firmly into position without any bulging or expanding, thus making a perfectly tight metal to metal joint, the pressure of the boiler tending to tighten it.

Inner or Field Tubes.—These are 2in diameter and made of comparatively light iron, the tube being in equilibrium. They are held concentric in the large tubes by lugs (C) at intervals, the front end is belled out and slips into a split jointing ring (D) which clips the division plate and makes a joint. These tubes fall 2ft. short at the back end.

Header or Closure Lids.—Fig. 2, plate 1, shows the Dürr Patent internal lid for closing these holes. These lids being larger than the holes, it is impossible for them to blow out. In place of the ordinary crossbar there is a circular cap taking the bearing all round and pulling these taper lids up firmly, again making a metal to metal joint without packing, the pressure tending to tighten. The advantages of this joint will be apparent in face of the many accidents through the blowing out of external lids, through the breaking or slipping of a crossbar or pin. The pin and lid of the Dürr closure are one forging.

Large Tube Closure Lids.—There are several patent lids for the closing of the rear ends of the large tubes. Fig. 2 shows the latest type for land boilers. This is also a metal to metal joint, the end of the tube having been thickened up by an internal welded taper collar, the pressure again helping to tighten. There is also an external type of lid for closing tube ends.

Fittings and Accessories.—The boiler has the usual complement of steam and furnace fittings, an anti-priming pipe, extra long, perforated with very small holes on its upper surface leading into a closed dome; this insures dry steam, which can be relied upon. Plate 2 shows a photograph of the front view of four boilers at work.

Superheating—For high speed engines it is an advantage for the steam to be superheated to prevent loss by condensation in the steam pipes, and a considerable saving is effected. Plate 1 (E) shows the usual small tube bent type of superheater which superheates the steam 100°F. or more, suitable arrangement being made for flooding and regulating.

Cleaning Doors.—Light sheet iron cleaning doors (D) are fitted to both front and back of boilers and can be at once removed for inspection of joints while boiler is working.

Generally.—The whole of the parts of the boiler under pressure are made from Siemens mild steel, no cast-steel being used, and upon completion tested by hydraulic to 1½ times their daily working pressure. These boilers are to-day being built by us under the inspection and to the satisfaction of The Boiler Insurance Companies who have passed the detail drawings without any alteration. Having briefly explained the construction of the boiler, we will consider its advantages under working conditions.

CLEANING.—Thereare many Water-tube boilers which have the chief features of a good boiler, with the exception of facility for cleaning, and the designers do not appear to have considered as to how they shall be efficiently and promptly cleaned at intervals All boilers, no matter what are their construction, ought to have good feed water, and the feeding of boilers with water containing 40 to 60 degrees of hardness should be a thing of the past; but it is the exception, not the rule, to find any good apparatus that effectually reduces the temporary hardness to reasonable limits, and the scaling hammer is in great request on boiler cleaning days It is possible with cylindrical type boilers to feed them with almost any kind of water, allowing the sediment to deposit in thick cakes on the tubes and sides of the boiler, but it is well known how this reduces the efficiency of the heating surface and life of the boiler. The Dürr Boiler, or any other water-tube boiler, will give trouble through overheating if fed with the hard water previously mentioned, and, while it is not necessary it should be free from sediment, it is advisable that this should not exceed 25° of hardness to obtain good

results. It is to be hoped that in the near future apparatus for the purifying of the feed water, several good and efficient types of which may be obtained, will be taken advantage of, and that steam users will be as particular about their boilers being fed with pure water, as they are to-day careful that grit is not present in their lubricating oil.

It will be noticed that there is a manhole at the rear end of each drum; also that blow-off cocks are fitted at this end, being the quietest place in the boiler where any deposit from the feed water which is delivered here may settle, and be blown off; by this means the sediment is to a large extent kept out of circulation. Each tube has a cleaning door opposite, and upon removal of the lid the inner tube can be immediately removed, and what scale is deposited upon its inner or outer side easily cleaned off, and as the water remains in the tubes after the boiler is blown off for cleaning, whatever scale is formed does not cake and become baked hard upon the sides through the heat (as is the case when the tubes are emptied in the usual type of boiler and left standing), so that this soft scale ean be easily removed with the tube brush or scraper. With fair feed water it should not be necessary to clean oftener than every few months, and then only two or three rows at a time. When the cleaning of these large straight tubes with handholes opposite, is compared with the cleaning of small tubes, bent in all manner of shapes, the advantages are readily seen, and this is a point of great importance for the satisfactory working of a water-tube boiler.

The flame rising at right angles through the mass of tubes and again turning downwards leaves deposits upon the upper surface of the tubes, which can be blown off with the steam brush through the small openings placed at intervals along the side of the brickwork, and level with the tops of the various rows of tubes. Side flue doors are also fitted into the brickwork both above and below the tubes for cleaning purposes.

REPAIRS.—In examining the advantages of one boiler over another, the question of repairs is amongst the foremost considerations. A good boiler should be of such construction that any wearing part subjected to fierce heat may be easily replaced or repaired. As the drums of the Dürr Boiler are of comparatively small diameter and well built, and are not subject to great heat, they will not require any repairs for many years. It has been proved by many years of continual working that no repairs whatever are necessary to the headers which are solid welded throughout, having no laps or rivets. We now come to the tubes, which are the vital point; and it is here that the trouble has been with both water-tube and multitubular boilers. It is but natural when a large tube 18 feet long is expanded or beaded into two fixed points that the expansion and contraction will cause something to go, and fractures and leakages are the result, and as there is a difference of temperature between the bottom and the top tubes, this is the cause of fractured sectional headers, or one or more bent tubes. None of these troubles

can take place with the Dürr tubes, which are connected at one end only, thus leaving the other end to freely expand. The replacing also is a matter of a few minutes after the steam is down; a few sharp blows with a wooden mallet at the rear end of the tube drives it out of the taper hole in the header. But in the case of a tube which is expanded at both ends, should this require replacing through bulging or fracture, it is a most difficult matter, especially if it should happen to be near the centre, and with sectional headers it is often necessary to remove one for the defective tube to be taken out; this takes a long time, sometimes days. As the lower rows of tubes receive the fierce heat of the flame they naturally wear out much quicker than the upper rows. When the Dürr tubes show signs of wear, they may be replaced by the upper ones. All tubes being interchangeable, they can be removed without damage to the tube or joint. This cannot be done with any expanded tubes, the removing spoiling the tube.

It will thus be seen that the Dürr tube has considerable advantages considered from the standpoint of repairs.

CIRCULATION.—Rapid and constant circulation is a necessity especially in water-tube boilers, because with a small volume of water in the tubes over the fire, steam is very quickly generated, and unless it can get away freely, steam pockets will be formed, and if there be no water present to take up the heat the tubes will become overheated in these places and bend or burn through. This does not occur with boilers having good circulation, fresh water filling up any void.

Professor Watkinson, in his paper before the Institution of Naval Architects, in 1896, gives the following three main causes of circulation:—(1) "The difference in density of water due to difference in temperature when the fires are first lighted. This circulation is very sluggish. (2) When the water is approximately at the same temperature and steam is being generated, but not with sufficient rapidity to cause a break in the continuity of the water, a very much more vigorous but mainly local circulation is set up by the entraining action of the bubbles of steam rising through the water. (3) When steam is generated with such rapidity that in some parts of the circuit there is steam or foam only present, a very rapid circulation takes place, due to the difference in density between the steam or foam and the continuous water in the down comers, internal or external."

In boilers with free circulation, such as the Dürr, the circulation is partly due to the action of the steam bubbles moving through the inclined tube; but mainly to the difference of density between the column of steam and water in the outer tubes and rear half of the header, and the solid water in the outer half.

It will be noticed that the circulation of the water coming in from the feed valve is as follows:—The water enters at the front of the right hand

upper drum, passes through the internal feed pipe to the back end, turns along through the connecting passage into the left hand drum and along towards the front, descending through the hopper leading to the outer side of the header; it then enters the small inner tubes, travelling towards the back end where these tubes fall short some 2ft.; turning, it ascends through the large inclined tubes, as it rises it is rapidly generated into steam, emptying itself into the rear portion of the header, and through the hopper above the water line in the drum. The efficient circulation caused by the inner or "Field" tube principle is well known, and this circulation may be watched through the glass windows placed in the header, in the working model I have with me Some sediment has been placed in the water, so that the water descending on the outer side and the steam and water ascending rapidly on the inner side of the header may be very clearly seen. This action may be likened to the racing of steam and water through the tubes, and it also tends to keep the passages clear. This constant circulation maintains all parts of the boiler at a uniform temperature.

In the Dürr Boiler there is a large area in the connection of the header to the drums of not less than one-fifth of the area of the tube it supplies, on account of which the boiler may be heavily forced; but in many types, especially those having sectional headers, the area of circulation is restricted where the connection is made to the steam and water drums, and may be taken as an eighth of the area of the tubes supplied, though sometimes is only a tenth, and as those nearest the fire are of course farthest away from the connection to the drum it can fairly be claimed that the circulation through the lower rows of tubes is interrupted, and that consequently with heavy firing such tubes will get overheated Only recently such an instance was brought to our notice.

We asked a certain firm of stokermakers to quote us for chain grate stokers, knowing that they had constructed and applied them to ordinary water-tube boilers; but their reply was, that they had to discontinue the manufacture of this stoker, finding that the intense heat which this machine caused the fuel to generate resulted in frequent stoppages for replacing of tubes. The following table shows result of experiments made with boilers having Field or inner tubes, from which it will be seen that the first four rows of tubes evaporate more than half of the total amount of water, clearly showing the necessity for the steam generated in the bottom rows to rise freely and unrestricted.

Trial of Tube Evaporation.

1st row	of tubes evaporated,	22·5	of total water evaporated.
2nd	,,	14·5	,,
3rd	,,	10·55	,,
4th	,,	8·75	,,
5th	,,	7·48	,,

6th	row of tubes evaporated,	6·54	of total water evaporated.
7th	"	6·20	"
8th	"	5·63	"
9th	"	4·95	"
10th	"	4·60	"
11th	"	4·40	"
12th	"	3·90	"

Steam.—The steam is mainly generated in the ascending part of the outer tubes and owing to the rapid generation is charged with moisture,so on entering the right hand upper drum, it then passes along and through the saddle piece into the left hand drum, its velocity becoming considerably reduced, and after passing through the perforated pipe, we have perfectly dry steam in the dome.

Combustion.—The problem is to generate as much heat as possible from one pound of fuel, and to utilise it under the boiler. Perfect combustion depends upon a thorough mixture of the gases, and to get this, air must be admitted both under and over the bars in a correct quantity. That this is not easy to procure in the every-day working of a boiler is shown by the escape of smoke and unconsumed gases In the Dürr Boiler the grate is kept well down below the first row of tubes to allow of the gases being thoroughly mixed and heated to a high temperature, before leaving the combustion area; they then pass four times across and between the staggered tubes, impinging upon them and not gliding by in parallel lines as in Lancashire boilers, so that on reaching the back flue the temperature is usually between 400° and 500°.

Efficiency.—As will be seen from the following table, the Dürr Boiler under the numerous trials is proved to be economical, utilising 65 to 75 % of the heat value of the fuel, which means quick steam raising, and a large evaporation per pound of coal consumed, this result being obtained by rapid circulation, good combustion of the gases before entering the body of tubes, and the efficiency of the heating surface, by having a long row of bottom tubes and not more than seven or eight rows deep.

Evaporation Tests of the Dürr Patent Water-tube Boiler

No.	Heating Surface, square ft.	Grate Area, square ft.	Efficiency Per Cent. Heat value of Fuel utilized.	Steam pressure, lbs. per square inch.	Temperature of Gases at end of Boiler.	Cold Water evaporated, lbs. per hour.	§ Lbs. of Water per lb. of Fuel from and at 212° F.	* Heating value of Fuel, B.T.U. per lb.	Lbs. Fuel burnt per square ft. Grate per hour.	Year of Test.
1	2727	56·0	72·2	154	411	5310	8·2	11065	13·0	1897
2	1688	33·0	69·9	117	593	5600	9·5	13712	21·0	1891
3	2450	52·0	64·7	156	450	4650	7·6	11350	17·8	1895
4	2160	76·0	69·5	141	440	4060	8·9	12400	14·5	1895
5	2450	52·0	72·5	146	430	7350	8·4	11170	19·6	1895
6	2450	34·5	74·6	145	430	6850	8·6	11250	27·5	1895

§ It will be noticed that the heating value of Fuel is only about 75 per cent. that of best Welsh coal.

* With best Welsh coal from 9·5 to 10·5 lbs. of water will be evaporated per lb. of Fuel.

Patents.—The construction of the Dürr Boiler is protected by several patents, but the principle of the field or inner tube is a well-known one, and has been used to the greatest advantage; the various patents being for the improved methods of fastening the tubes, and the front and back closure lids, resulting from actual practice in the building and working of 1,500 boilers, and proving to be a perfect metal to metal joint for the tubes and lids, which is the essential point insuring safety and efficiency in working.

Brickwork Setting.—This will be seen on referring to Plate 1 to be of ordinary construction, the boiler being supported to a large extent by girders, and able to expand freely. The tubes are divided into four partitions through which the gases have to pass in a circuitous form, so that the temperature on leaving the boiler is comparatively low. The ground space occupied by the boiler is one-third less than that of the ordinary Lancashire. Plate 3 shows two boilers in course of erection.

Constructional Comparison of Various Types of Boilers.—Water-tube boilers generally have a large amount of heating surface, and, given good combustion, generate steam rapidly and are more or less efficient; but as the conditions under which tests of the various water-tube boilers are made, differ so considerably, it appears to me that the best means of comparing the advantages or disadvantages is by the four main points. (1) Construction, (2) Circulation, (3) Cleaning, and (4) Repairs. As it is impossible to describe in a few words the particulars of some of the types at present in use, the slides I have illustrating them will be the best method of quickly and graphically bringing them to remembrance.

Marine Type Boiler.—The Marine type boiler is built upon the same principles as the Land type, but is more compact, to reduce space and weight.

For many years past the discussion of Water-tubes *v.* Scotch Marine Type has been a keen one, and while there is no doubt that the Scotch boiler has reached a high state of perfection, yet the advantages of the Water-tube, particularly for War Ships, are so great that there seems little doubt that they will hold their own. The main advantages are—(1) The rapidity with which steam can be raised from the time the fire is lighted in the grate, being only from 40 to 60 minutes. (2) Far greater power output in proportion to weight. (3) Less cubic space required. (4) Greater safety, no danger of vessel being wrecked by explosion. These advantages so appealed to the Admiralty that since 1892 they have been fitting up the majority of our ships with these boilers, and the only regrettable part is that they should have adopted the Belville type with its tortuous passages, inefficient circulation, and necessity for automatic feed before the boiler had been exhaustively tested alongside with other types of Water-tube boilers. In August last, the Admiralty Boiler Commission condemned the Belville, and selected,

after careful inspection, the Dürr Boiler as one that fulfilled the conditions, and placed an order for eight boilers for the "Medusa," (see Plate 4), each of these boilers having 2,500 square feet of heating surface and a working pressure of 250 lbs. per square inch, and have also since placed a further order for boilers. We may expect shortly to hear that this type of large straight tube boiler has fulfilled the requirements in our own, as in other Navies. The Fairfield Shipbuilding Company have taken up the Marine Rights to build them in this country.

These boilers have three main elements—(1) Upper steam and water drum. (2) Welded header (which is common to all tubes). And (3) Dürr tubes. The main differences are that the drum is placed across the header, instead of being parallel with the tubes, and of much smaller size. The header is also placed vertically instead of at an angle, and the tubes (seamless drawn), 3½in. diameter, are only about 7ft. long. The superheater is placed above the boiler tubes, and the jointing of the tubes is effected by fixing their conical collars into the taper holes of the tube plate, as before described, and the internal tube is also inserted and fixed to the division plate in the header.

The ashes collecting on the outer surface of the tubes are removed by steam jets introduced from the side or back, also at suitable centres the stay bolts are hollow to allow of the steam jet being used from the front. Perhaps the best method is to close all doors except the funnel damper, and by means of a blower obtain a pressure of two inches of water; the sharp draught thus generated drives the soot accumulations from the boiler through the funnel without interfering with steaming.

Circulation.—This is very rapid, and the boilers can be highly forced to consume as much as 60 to 70 lbs of coal per square foot of grate, with forced or induced draught, without detriment. The tubes can all be well cleaned from the front end on account of their being of the large straight tube type; in case of faulty or damaged tubes they may be replaced in a few minutes when the steam is down. The whole of the boiler is cased in with sheet iron and asbestos lining, having sliding doors at front and back for cleaning and removal of tubes. The improvements in detail which have been made from time to time in the building and working of the large number of boilers now made, along with efficiency, as shown on the following particulars of tests, place this boiler at the front.

The following table gives particulars of some Navy boiler trials:—

Trials of Dürr Marine Boilers.

		NAME OF SHIP.								
		"Rhein."	Experimental Boiler.	"Baden."	"Bayern."	"Sachsen."	"Victoria Louise."	"Vineta."	"Prince Heinrich."	"Prince Albert."
Built in		1893	1895	1896-7	1897	1897	1897-8	1897	1900	1901
Firm		Dürr	Dürr	Germania Werft.	Schichau	Dürr	Dürr and Weser Co	Dürr	Dürr	Dürr
Number of Boilers		1	1	8	8	8	12	12	14	14
CHIEF DIMENSIONS OF A BOILER.										
Working pressure ...... lbs. sq. inch		199	213	185	213	185	213	185	213	191·7
Grate area .... sq. feet.		38·3	54·25	64·6	56·73	54·68	56·10	50·3	72·00	70·65
Heating surface, water-washed, sq. ft.		962	2402·5	2088	2722	2155·5	2320	2108	3058	3000
Ratio, grate area to heating surface		1:25	1:44	1:32	1:47	1:39	1:41	1:43	1:42	1:42
Surface of superheater tubes, sq. feet		36·27	204·36	87·72	117·1	127	178	118·4	108·3	170·74
Steam space in receiver, excluding superheater .... cb. feet.		81·22	56·36	52·37	133·85	63·21	46·05	59·33	114·07	129·06
RESULTS OF EVAPORATION TRIALS.										
Coal burned per sq. ft. of grate per hour lbs.	a	—	20·3	—	19·8	28·3	17·6	—	15·3	—
	b	—	29·5	—	27·2	28·7	—	—	31·1	—
	c	—	40·95	—	—	—	—	37·1	37	—
Water evaporated per hour per lbs. of coal (reduced from and to 212° F.	a	—	9·39	—	10·11	—	11·1	—	11·57	
	b	—	9·26	—	9·68	9·06	—	—	9·92	—
	c	—	9·13	—	—	—	—	8·9	9·379	—

Summary of Advantages of the Dürr Water-tube Boilers.

1. Perfect circulation due to large distributing area in uptake.

2. Circulating water kept in closer contact with the heating surface, than is the case with the ordinary water-tube ; this due to the internal water-tube system.

3. Freedom for expansion of each separate tube, as they are held rigid at one end only, and thus distortion and fracture, with consequent leakages, are avoided.

4. All joints are metal to metal, without any expanding or screwing.

5. Perfect safety, the tubes being held in position by means of a taper joint, and the lid being of the inside closing type. The tendency of increased pressure is to tighten the joints.

6. Easy method of cleaning and replacement of tubes, if necessary, without liability of damaging any joint surface. The whole of the tubes are interchangeable, and only a few minutes are required to remove and replace a tube A further advantage is that the lower tubes, which receive the fiercest heat, can after a time be transferred to the upper portion of the boiler.

7. Sediment kept out of circulation, due to quietude of water at feed inlet, thus reducing attention to cleaning and cost of upkeep.

This boiler can be considerably forced beyond its rated capacity, without detriment and without any appreciable loss in economy. Some, 250,000 horse power, of which a considerable portion represents repeat orders, are in use.

These boilers are particularly suitable for being fired by the waste heat from furnaces in steel and ironworks, on account of their large heating surface.

THE DISCUSSION.

THE CHAIRMAN : The paper to-night has been upon a comparatively new subject, and one which intimately concerns the economical management of iron and steel works. There can be little doubt, after what we have heard from Mr. Thompson, the Dürr Boiler is a quick steam generator and comparatively safe. Its application to land practice interests us most as ironworks managers, and I should like to hear the views of some of the gentlemen present upon this particular feature of the paper. The members will have noticed that Mr. Thompson lays special stress upon the necessity for using clean water if this new boiler is to be a success. For us in South Staffordshire that is a very practical point, and one of some difficulty. Under such circumstances, how far

the Dürr boiler will commend itself to the Black Country district of England is a question upon which it is impossible to come to a hasty decision.

Mr. H. Parry: I have been pleased with the clear way in which Mr. Thompson has dealt with a technical engineering subject, and all of us must have gained information. Given good feed water and fair treatment, I am disposed to agree with the author that the type of boiler he has described will prove a success for steam raising purposes on land, in the same manner that it has done, and is still doing, at sea. The points he has enumerated are all in its favour for land service. I refer especially to its large heating surface; easy access for cleaning purposes; and the readiness with which repairs can be made. Again, its adaptability for gas firing, by either blast furnace or other gas, is a distinct recommendation in times like these when the increased utilisation of blast furnace gases, and Mond gas, for firing is so prominently before the public. Gas firing is naturally an advantage to any boiler. There is one point upon which I should like a little information from the author, more in relation to naval than land boilers, and that is whether the Dürr boiler is of a suitable type for the employment of liquid fuels. The subject, which has been treated this evening, must always be an attractive one to this Institute, since the care and treatment of the boilers is a cause of anxiety to all works' managers, whether in this district or in the other iron and steel making centres of the Kingdom. This is exceedingly so in view of the inauguration of the recent new Government regulations requiring periodical inspection of all boilers by qualified inspectors. The fewness of explosions which have had to be recorded in South Staffordshire of late years shows, I think, that we have given universal attention to the matter of boiler efficiency and safety. By the steady abolition of the old cylindrical boiler, and the substitution of boilers of more modern construction and design, including water-tube boilers, either of the Dürr or other patterns, I have very little doubt that the risk to life and limb, and also to works property, necessarily arising from all steam boiler employment, will be further very considerably minimised. Another conspicuous advantage of the progress of the steam boiler construction and engineering science, is seen in the increasingly high efficiency of the various types put upon the market, and of their diminished consumption of coal. This last, so long as fuel remains at its present high price, must unquestionably be an important consideration with all of us. I rather expected this evening that Mr. Thompson's paper would give rise to a discussion on the relative advantages of steam driving compared with gas engine practice; but it has not done so. One thing however is clear, and it is becoming clearer every day, namely, that unless steam boilers are made thoroughly efficient, both in the matter of economy and many other points that might be mentioned, large power gas engines will become the motive power of the future of most of the works in the Staffordshire district.

Boiler engineers in their own interests would be well advised in bearing this possibility in view.

Mr. H. MOORE: I understand that one of the objections taken to the Belville boilers by the British Admiralty was that the tubes employed cannot be made in this country—a matter of importance and difficulty in time of war. I should like to know whether the same disadvantage attaches to the Dürr boiler tubes, or whether the steel and tubes can be obtained in our own country?

Mr. C. E. BLOOMER: Mr. Thompson's paper is a most interesting communication, and its value has been much increased by the limelight illustrations, showing the different types of boilers described. The author has made it clear that water-tube boilers will take preference of Lancashire boilers in future, even in land practice. Coal at present time is very dear and there seems to be little likelihood of its becoming cheaper. Under these circumstances works' managers must make every effort to get more power from the same amount of coal as they are burning to-day in order to effect economies; and if either the Dürr or any other type of water-tube boiler can materially assist to this end we can promise it a hearty welcome. One portion of Mr. Thompson's paper greatly surprised me. It was where he described the tubes of the Dürr boiler as lap-welded steel tubes. I thought that at any rate as regards the Admiralty practice, the tubes were drawn solid from solid steel blooms, and that the Admiralty specifications made this feature an absolute *sine quâ non*. Why in land boiler practice this has been changed to welded tubes he has not told us. Perhaps he may have sufficient reasons, but we should like to hear what these are and why he has made the change. Solid drawn tubes would have been much more reliable, and therefore much superior in every way. A few years ago there was a very serious accident to one of our cruisers fitted with Belville boilers, which was directly due to one of the tubes bursting. At the time it was reported that the accident was due to lap-welded tubes having been put in, and I think that the Admiralty then wired orders to the contractors that in future nothing but solid drawn tubes were to be fitted. Whether lap-welded or solid tubes are used, no doubt British tube makers will gladly welcome the innovation of the water-tube boiler into land practice. It will be well within the recollection of the Institute that only quite lately, at the time of the cycle boom, steel cycle tubes were so much sought after that many British tube firms went specially into the cycle tube business and laid down expensive, and extensive, plants for cycle tube manufacture. Since the "slump" in the cycle trade, however, a very different state of things prevails. Many of these special plants have now little or nothing to do, and the tube makers are once again only too anxious to secure steam tube orders—a class of business which during the cycle boom they simply neglected. Firms who were then too busy to give attention to steam tube orders are now

laying themselves out afresh to make steam tubes in any quantity, from 2in. up to 4in., and 4½in. diameter. It is satisfactory to know that the English tube trade is capable of supplying anything that may be demanded of it, by the progress or requirements of the most modern engineering practice I know that the Admiralty have specified that all the tubes employed in their new boilers shall be exclusively of British manufacture.

Mr. JAMES THOMPSON, speaking as a visitor, said he should be glad to be allowed to make a few remarks. He remembered with pleasure being at a meeting of the Institute some years ago, when a most interesting paper was communicated upon "Boiler Explosions and their Prevention," by Mr. E. B. Marten, who spoke from wide experience. The interest which was excited in Mr. Marten's paper still existed, he believed, among members of the Institute, and this feeling partially dictated the paper of that evening by his brother. In view of his relationship with the author of the present paper, he did not propose to make any remarks thereon, but he had risen mainly to impress upon the members the urgency of the water question. It was essential to the success of the water-tube boiler that it should have good water. If any objections were raised, and this demand was considered severe, he would point out that the province of a steam boiler was to generate steam, and not to bake cakes. This was a point which makers of boilers, especially those of the water-tube class, must insist upon. He admitted that the South Staffordshire district was a difficult one, perhaps more so than any other part of the country, as the water used was largely that pumped from the mines and from the canal, both admittedly terribly bad. It was one, however, which should be met, and the necessity for dealing with it was every day becoming more apparent. The adaptation of the water-tube boiler to land practice formed the latest call upon steam users and works' managers to attempt reform.

In travelling in other countries during the past two or three years he had been struck with the circumstance of how far this country, and the South Staffordshire district in particular, was behind hand in the matter of boiler water purification, As an instance, at one works alone he found that no fewer than 300 water softening plants were being turned out each year, as great a number he believed as were in use in the whole United Kingdom.

The speaker concluded by expressing the opinion that steam users and works' managers, having the charge of numerous boilers ought not to give water softening and purification plant "the cold shoulder," as was now too frequently done. As a district, Staffordshire was making a great mistake in exhibiting so little interest in this essential, and the wider adoption of water-tube boilers would bring this home.

On the proposition of the CHAIRMAN, seconded by Mr. JAMES PIPER, the Author was heartily thanked for his paper; the CHAIRMAN remarking

that while it was difficult to express immediately any very definite opinion on the merits of the Dürr system over other types of water-tube boilers for iron and steel works purposes, Mr. Thompson's communication might very probably have a favourable result.

Mr. S. J. Thompson, in replying on the discussion and acknowledging the vote of thanks, said: If more fault had been found with the paper, or if it had been more widely criticised, I should have been, if possible, more pleased than at the kind reception which the paper has met with at your hands. I agree with the Chairman that it is very difficult to form a definite opinion in the course of a short paper and debate upon the merits and demerits of water-tube boilers, as compared with the Lancashire type of boilers. I may say that the tubes of the Dürr water-tube boilers will certainly be made in England. There is nothing about their design or construction which renders this impossible. We shall not have to go abroad for any part of the boiler. Indeed if you were to suggest to any of the leading British tube firms that they were unable to manufacture tubes just such as I have described and illustrated this evening they would be astonished. I may just state here that my firm have been approached by large tube firms of Wednesbury and Glasgow for the contract to make the Dürr boiler tubes. They are of ordinary lap-welded manufacture, of simple construction, and very suitable for the tube works of this district, and the collar is either staved up or else welded on. The length is about 18ft., and in the large sizes the thickness of the material is $\frac{3}{16}$in for the lower rows of tubes nearest the fire, and $\frac{1}{8}$in. for the upper rows. A question was asked about the adaptability of the Dürr boiler to liquid fuel firing. To that I have to give an answer in the affirmative; these boilers can be fired, if desired, by liquid fuel in the ordinary way. As we know, however, that liquid fuel firing requires rather a special fuel, and in the Staffordshire district, where the price of fuel, though just now high, is in a normal condition of the market, comparatively low, liquid fuel firing would not possess any advantage. In Russia and some other countries liquid fuel has been used, and has given good results. One speaker has referred to the possible utility of the Dürr boiler in connection with the utilisation of blast furnace gases. For this utilisation much economy is rightly claimed. In this situation the Dürr boiler would act quite satisfactorily. The water-tube boiler is indeed essentially one which lends itself to this waste heat utilisation. At one works the Dürr boilers have been put in where the gases were running away in large quantities at a temperature of 1,600 degrees, and there must be many other cases where gas is escaping at similar high temperatures, which, by the judicious employment of modern plant might be saved and made profitable. I should like to emphasise all that has been said by my brother, and to which too I referred in my paper, about the necessity of using clean water with water-tube boilers. We say that it is essential to their effectiveness that something like reasonable water should be used in feeding. I will now

pass to the question of efficiency of the boiler as a steam raiser. Efficiency is one of the strong points. If members of this Institute who work boilers have taken tests, they may have found that the efficiency of their plants frequently comes out at 5lbs. of water converted into steam per 1lb. of coal consumed. We can do better than this; we guarantee the utilisation of 70 per cent. of the heat efficiency of all the fuel consumed. It is probable that many of the boilers in this district are not securing more than two-thirds of this heat efficiency. In reply to Mr. Bloomer, I may remark that, as he suggested, it is certainly better to have seamless iron tubes, but the objection is that steam users are not generally prepared to indulge in the cost of such expensive materials. My hearers will bear me out that, unfortunately, in laying down new boilers the matter of first cost is too often regarded as the chief matter of importance. The Admiralty occupy a unique position in this respect. Mr. Bloomer is quite correct when he states that the Government have stipulated for solid drawn tubes in all their water-tube boilers; but then the Admiralty have unlimited money at their disposal. The bottom rows of tubes which receive most heat from the fire will be solid drawn; but for the last ten or fifteen years lap-welded tubes have been generally used in steam boilers and have answered very well, and my firm see no reason why in the water-tube type of boiler they should be altogether discarded.

The meeting closed with an inspection by many of the members of a working model of the Dürr boiler which was upon the table, and which illustrated more particularly the system of the circulation of the water.

The seventh Meeting of the Session was held at The Institute, Dudley, on Saturday, the 12th April, 1902.

THE PRESIDENT (Mr WALTER SOMERS) presided.

The minutes of the previous meeting were read, adopted, and signed.

Messrs. S. J. Thompson, Holbury Mensforth, B. J. Green, and H. G. Mantle were elected members of the Institute.

On the proposition of Mr. SAMUEL WESTWOOD, seconded by Mr. JOHN BATE, Messrs. Richard Round and James Raybould were elected Auditors of the Institute accounts for the year ending 31st December last

THE PRESIDENT introduced Mr. W. H. THORNBERY, who read the following paper :—

WHEEL GEARING

By W. H. THORNBERY, M.I.Mech.E.

(BIRMINGHAM).

When your Past President, Mr. John W. Hall, did me the honour to ask me if I would read a paper before your Institution, I was placed in a position of some difficulty, as on the one hand my general practice had not led me specially into the study of the technicalities of subjects such as are commonly brought before you, as blast furnace working, or the details of steel and iron making and the like; and, on the other hand, some subjects more in my own line, on which I might have addressed you, as for instance, Steam Engine Indicating and Modern Methods of Power Distribution by Electricity, both from large Central Stations and smaller installations in works, had been recently dealt with in very able papers which have been read before you.

In this difficulty I have ventured to write on a subject which is a very old one, and which has already been dealt with by many engineers and mathematicians. My excuse is, that, though old, the subject is of perennial interest in one way or another to almost everyone who has to deal with machinery, and though so much has been spoken and written about gearing, yet it is very evident to an observant engineer, that a great deal of wheelwork that is in daily use is not so well designed, made, or maintained, as it might and ought to be, and in consequence there is a large amount of power lost in friction and backlash, and occasionally a breakdown, with results sometimes disastrous and always inconvenient.

MAIN GEARING.

For a long while after the introduction of steam power for the purpose of working the cotton and woollen mills in Lancashire and Yorkshire, the use of toothed gearing was universal. Power was delivered from the main shaft of the engine by means of spur gearing, latterly very largely by Fairbairn's method of forming the fly-wheel of the engine into a spur wheel, and taking the power directly from it by means of a pinion gearing into it and keyed to a second motion shaft. From this second motion shaft a pair of mitre wheels gave motion to a vertical shaft, from which a main line shaft on each floor of the mill was driven also by means of mitre wheels.

This system of power distribution, as you know, has been largely superseded by driving by means of wide belts, and more recently by cotton ropes; and, undoubtedly, for such a purpose as above mentioned,

belts or ropes have many advantages over toothed gearing. But in the Lancashire district, at the present time, rope driving is not so much used as formerly, steel toothed wheels have superseded it in many cases. I am quite aware that the advocates of rope driving are extending the system in many directions in which toothed gearing and shafting have until recently been supposed to be the only practicable means of conveying power, as for instance, to the driving of light roll trains in ironworks.

But for the transmission of power for such purposes as rolling mills for iron, steel, brass, copper, and other metals, and also for a large number of miscellaneous power transmission purposes, toothed wheels are, and will be largely used; and in machinery where power has to be transmitted only in small amounts, but where regularity and exactitude of motion are of the utmost importance, toothed wheels of various kinds are, and will continue to be, absolutely necessary, except where the modification of chain driving is employed.

Moreover, when toothed wheel work is made and maintained in the best manner, there is less loss of power by its use than by the use of the other means of power transmission that I have mentioned.

In all toothed wheels, from heavy trains of six inches pitch, or even more, as used in mill and forge gearing, down to the very smallest as used in watches, the general principles governing the shapes and the proportions of the various parts are the same, though in some applications of wheelwork some considerations may be practically ignored and attention may be concentrated on others. One of the first applications of toothed wheels was in the construction of clocks. Here the transmission of power is a minor matter, what is most required is accuracy of motion. Some of the earliest researches into the principles which should govern the shape of the teeth of wheels were made in connection with clockwork.

The members of an Institution such as yours will, however, be much more interested in questions dealing with toothed gearing as applied to the transmission of large amounts of power than to such considerations as belong to wheelwork used in, and forming part of, light machinery of various kinds, but there is one fundamental and most important respect in which all designers of wheelwork for whatever purpose are interested, and that is the shape of the teeth, and to this branch of the subject I propose to pay special attention. Toothed wheels are used for several purposes, as—

1. To transmit motion from one revolving shaft to another.
2. To transmit power from one revolving shaft to another.
3. To change the velocity ratio of two revolving shafts.
4. To alter the direction of motion.

Purposes Nos. 1 and 2 are not identical, in theory at least, for if the only object were to communicate motion it might be done by the edges of discs on the shafts bearing against one another, and the one driving the other by friction. Of course the friction would be caused by small roughnesses on the edges of the discs; but it is convenient to bear this theoretical case in mind as the starting point of our investigations

Purpose No. 2, necessitates teeth being placed on the edges of our previously smooth-edged discs, so that when the discs or wheels are in gear, if the one move, the other must move in a corresponding manner.

Purpose No. 3, necessitates the wheels which gear into each other being of different sizes.

Purpose No. 4, necessitates the wheels being made bevil or mitre, that is to say, instead of their theoretical acting surfaces being edges of discs, they are frustra of cones having a common apex.

SHAPE OF THE TEETH OF WHEELS.

I must ask your kind indulgence when stating some very elementary facts, which, however, I find are frequently ignored in practice. To simplify matters, while investigating the shape of the teeth of wheels, I will deal only with spur wheels. The forms of the teeth of bevel and mitre wheels are arrived at in precisely similar ways, but they are drawn on the development of the frustrum of a cone, instead of on a flat surface.

My friend, Mr. A. E. Tucker, has been good enough to prepare some lantern slides for the illustration of this paper. I now place Figs. 1, 2, 3, and 4 on the screen. Take, now, two plain discs of equal size, place them so that their edges are in contact, then, if uniform rotative motion is given to one, it will communicate a precisely similar motion, but opposite in direction, to the other. Suppose that A revolves uniformly (Fig. 1), that is to say, at a perfectly unvarying rate, and sixty times in a minute, clockwise, then B will revolve uniformly sixty times in a minute, anti-clockwise.

Now, instead of the two discs, suppose two shafts, each having a kind of star wheel of four arms upon it (Fig. 2). Now it will be evident that if A revolve, as before, with a uniform unvarying velocity, and sixty times in a minute, B will also revolve sixty times in a minute in the opposite direction. But there will be this important difference from the previous case. When the end of the arm A1 presses on the corresponding arm B1 at a point very near to the shaft, it will, by its leverage, give B a much greater angular velocity just at that time. As B1 is driven round under the pressure of A1, its angular velocity will decrease, and when the end of the arm A1 is driving the end of the arm B1, the angular velocity of the two will be equal. When the arm A1 has slipped past the end of B1, then A2 comes into gear with B2, and the angular velocity of the star wheel B is instantaneously increased. Thus, although B makes sixty revolutions in a minute, the same as A, yet it does not do it in the same manner, but, as it were, by a series of

jerks. If we represent the uniform movement of the driver A during three seconds by a straight line, thus (Fig. 3), then the motion of B would be somewhat thus (Fig. 4). This is an extreme case, but it shows clearly that, although one wheel may be driven by another at a certain determined number of revolutions per minute, yet, that although the driver may revolve with perfect regularity, yet the driven may move by a succession of jerks.

Now we have already seen that when one disc drives another by friction, if the driver have a perfectly uniform velocity, then the driven will also have the same. But we are obliged to use teeth in order to transmit power practically, and the object in giving the teeth of wheels their peculiar shape, is to secure the same uniformity of motion that would be obtained by the use of discs, driving and driven by friction. Circles corresponding to the edges of such discs are called Pitch Circles, and the point at which these touch each other, and cut a line drawn from the centre of one wheel to the centre of the other, is called the Pitch Point. It has been ascertained that if teeth are so formed that their common normal at the point of contact passes through the pitch point, the velocity ratio will be uniform.

There are two kinds of curves, either of which, if properly used for the shape of wheel teeth, satisfy the above conditions, and will give uniform velocity ratios. In other words, if the driving wheel revolves in a perfectly steady and uniform manner, then the driven wheel will do the same. The names of these two curves are—

The CYCLOID (of which the epicycloid and the hypocycloid are special kinds), and
The INVOLUTE.

BACKLASH.

Before going further at this stage into the subject of the shape of wheel teeth, it may be convenient to consider briefly the subject of Backlash in view of the foregoing. Suppose that the two four-armed wheels A and B (Fig. 2) had a sensible weight, then, as A is revolving at a uniform speed, its momentum is unaltered. But B is being driven alternately fast and slow by every tooth or arm that comes into contact. Being heavy, it cannot respond instantly to impulses given to it, but when it is started to go fast it will tend to keep up its velocity by its momentum, and will over-run the driving arm, which will presently catch up to it and give it a blow. Thus, in wheels, the teeth of which are badly shaped, there is a Backlash from this cause, as the driven wheel is sometimes running faster than the driver, then it slackens speed, and the teeth of the driver give a blow to the teeth of the driven with which they are in gear. This backlash is due to the shape of the teeth, and is independent of anything that may be due to a varying load,or

to the unsteady driving that is due to the fly-wheel of the engine being too light.

Backlash is the cause of a great deal of noise and unsatisfactory working. Often heavy gear wheels will break when they are running without any load; this shows that they give way from shocks caused by backlash, and not from strains properly due to their work.

SHAPE OF WHEEL TEETH RESUMED.—CYCLOID.

The Cycloid, I may remind you, is the curve traced by a point in a circle rolling on a plain surface (Of its divisions into prolate and oblate I need not here speak, as these curves do not concern us). The Epicycloid is a curve traced by a point on the circumference of a circle which rolls upon another circle. The Hypocycloid is a curve traced by such a point rolling on the inside of another circle.

The Cycloid is used for the teeth of racks.

The Epicycloid is used for the points (or addenda) of wheel teeth.

The Hypocycloid is used for the flanks of wheel teeth.

INVOLUTE OF A CIRCLE.

The Involute of a circle is a curve produced by the motion of a point at the end of a string which is being unwound from a circle, or what comes to the same thing, a point in a straight edge rolled on a circle. Involute teeth have two advantages, first, that any pair of involute wheels of the same pitch will gear correctly together; and secondly, that even if the distance between the centres of the axes is altered by wear of journals or otherwise, the teeth still act correctly so long as they will drive at all. The disadvantage of involute teeth is, that there is more obliquity of action than in epi and hypo-cycloidal teeth. Involute teeth are used very largely in wheels where the teeth are cut, as for vast numbers of wheels in comparatively small machines. Now that the use of cut gears is extending to wheels of very large size, such as are used for transmitting very heavy amounts of power, the use of involute teeth is also extending. Some eminent firms who have taken up the manufacture of cut gear wheels use the involute form of tooth preferentially, cutting teeth involute unless the other form is specified.

But the epi and hypo-cycloidal form of tooth is more extensively used in the gearing of which most of my audience have to do. I will, therefore, proceed to discuss

EPI AND HYPO-CYCLOIDAL TEETH FOR WHEELS.

It is difficult to draw a cycloid, either plain, epi, or hypo, with exactness, and therefore methods are generally used to approximate to the correct curves by means of circular arcs. In practice this has nearly always to be done finally, as patternmakers can so much more conveniently work to circular arcs.

I will now show some methods of drawing the teeth of wheels by means of circular arcs approximating nearly to cycloidal curves. To avoid being too lengthy, instead of describing fully each method, I will refer to my authority in each case. In all the following diagrams of wheel teeth, I have taken the circumferential, or circular, pitch as four inches.

Method No. 1 (Fig. No. 5). Unwin's Elements of Machine Design, part 1, page 309. This gives an approximation so close that there is no appreciable difference between the cycloidal and circular arcs in gearing of any ordinary pitch. In this method a circular arc is found which exactly coincides with the cycloidal curve at the pitch line, and at two-thirds of its length from the pitch line, and which has at that point a common normal to it. By this method it is not taken for granted that the circular arcs are almost identical with the cycloidal, but the construction shows clearly that they are so.

Method No. 2 (Fig. No. 6). Kempe's Engineers' Year Book, for 1897, page 159. This method does not show by construction the near identity of the circular and the cycloidal arcs. It gives a good shape of tooth, and is identical with the method given by Nystrom, a Sweedish engineer, who printed it in his "Pocket book of Mechanics," first published in America in 1854. It is illustrated at page 180, of the edition of 1870.

Method No. 3 (Fig. No. 7). Ohren's method, published in the later editions of "Molesworth's Engineer's Pocket Book" This gives good results and is somewhat simpler than No. 2.

Method No. 4 (Fig. No. 8) Professor Willis's method. In this case the circular arcs are obtained by the use of an instrument called the Odontograph described in "Willis's Principles of Mechanism" at page 137, of the 1870 edition. This method is not so satisfactory as those previously described, and is not much used.

Other methods might be enumerated, but the foregoing are quite sufficient for all practical purposes. Personally, I much prefer method No. 1, as by that method I can see just what I am doing, and why I am doing it.

So far I have only described the method of forming the acting surfaces of the teeth so as to insure proper working as far as the velocity ratio is concerned. But to determine the shape of the teeth of a wheel we must also consider its thickness, and its height. In the ideal case of two wheels of material of equal strength, and the teeth of rigorously accurate shape working together, the width of a tooth measured on the pitch circle would be half the pitch, and the width of the space between the teeth would be the other half. But in practice, to allow for unavoidable errors in workmanship it is necessary to make the space wider than the tooth. How much wider it should be depends on the method by which the wheel is made. The difference between the width of the

tooth and that of the space is called clearance. It is least, being little or nothing, in machine-cut wheels, greater in machine-moulded wheels, the greatest in wheels cast from an entire pattern. For the different classes of moulded wheels the following are given by different authorities. I will give the dimensions in actual measurements for a wheel of four inches pitch :—

	At 4 ins. pitch Tooth.	Space.	Clearance ins.
Machine Moulded—			
Unwin	1·91	2·09	·18
Pattern Moulded—			
Unwin	1 86	2·14	·28
Do.	1·89	2·11	·22
Practice of a good English firm, but some years ago, now out of date	1·77	2·22	·45
Practice of a good American firm ...	1·90	2·10	·20
Nystrom (1870)	1·84	2·16	·32

The column marked "Clearance" in the above table is the difference between the widths of the tooth and the space in a wheel of four inches pitch.

I have shown two sets of two teeth with the space between them, the one set shows the widest, and the other the narrowest tooth mentioned in the above table. (Fig. 9.) When, as is sometimes the case, iron or steel toothed wheels gear with wheels with wooden teeth (mortice wheels) the wooden tooth is made much thicker than the iron one.

LENGTH OF THE TEETH.

The length of the teeth must be such that the proper number of them are always in gear, so that the driving may be continuous. When, however, this condition is complied with, it is desirable to keep the teeth as short as possible, in order to give strength. When wheels have short teeth it becomes, of course, all the more necessary that the distance apart of the centres of the shafts on which they are fixed shall remain invariable. Here I may say that theoretically, cycloidal teeth only work with perfect exactness when the pitch circles of the wheels rigorously touch each other, hence care should be taken that the distances apart of the centres of the shafts are exactly maintained.

Fig. 10 shows three teeth, each of four inches circular pitch, and of the greatest and least lengths respectively that I have met with in ordinary practice, You will see that the lengths vary considerably, the greatest being two inches and three quarters, and the least two inches and one quarter. Short teeth are preferable.

There is an erroneous statement, which I have often seen in print, to the effect, that if the teeth of wheels are properly formed, they roll on each other instead of sliding. This statement is quite inaccurate, as anyone may see who takes the trouble. The contact is a sliding one, except at the exact instant when the meeting surfaces of the teeth cross the line of centres, that is the line joining the centres of the shafts which are geared together. At that infinitesimally small portion of time the driving tooth simply pushes the driven

The friction between the teeth of wheels before they pass the line of centres is much more severe than after they have passed the line, just in the same way as the friction on the ground at the point of a stick pushed before you is more severe than that of a stick trailed after you.

This being the case it follows that if we can so contrive the wheels that all the friction shall take place after the passing of the line of centres, then the wheels will work with a smoothness otherwise unattainable. This may be effected in the following manner (Fig. 11). The driving wheel has its teeth formed only as "points," that is the portion external to the pitch line, and the driven wheel has its teeth only "flanks," that is the parts internal to the pitch line. In practice, and to allow for inaccuracies of workmanship, each kind of tooth is a little longer than the theoretical considerations called for, that is the "point" tooth goes a little inside, and the "flank" tooth goes a little outside the pitch circle. Wheels formed in this manner have the advantage of their teeth being exceedingly strong, but they have the disadvantage of being able to drive properly only one way, so that they are not adapted for trains of wheelwork such as those in rolling mills, where each wheel is a driver on one side and a driven on the other. In fact this is a special kind of wheel, and just like all other specialities it does its particular work better than any other kind of wheel, but it is not adapted to all sorts of situations. I am somewhat surprised, however, that it is not made more use of when the conditions are favourable.

But there is another method of attaining the same object, with teeth of the ordinary form. In this method, the driving wheel is of a pitch slightly greater than that of the wheel which it drives as shown in Figs. 11A and 11B. In Fig. 11B I have shown the whole circumference of two wheels which have each twenty-eight teeth, but the chordal circumferential pitch of the driver is four inches and one sixteenth, and the chordal pitch of the driven is four inches only. The diameters of the pitch circles are thirty-six and nine thirty seconds, and thirty-five and twenty-three thirty seconds respectively, a difference of nine-sixteenths of an inch. Wheels constructed according to this method are admirably adapted for trains of wheels in rolling mills, where each wheel in the train is a driver on one side and driven on the other. In such a case the pitch of the wheels would gradually diminish as they become more distant from the source of power. This diminution,

thought slight, would be in conformity with the requirements of the case, as less and less power would have to be transmitted as the distance from the prime mover increased.

WEAR.

To obtain the greatest possible uniformity of wear, the numbers of teeth of two wheels geared together should be "prime" to each other. When wheels would be of equal size irrespective of this consideration, the extra tooth introduced into one of them to make the numbers prime is called the "hunting cog."

PITCH.

"Pitch" in this paper, unless otherwise specified, is the so-called "circular" or "circumferential" pitch, that is, the distance from a point in one tooth on the pitch circle, to the corresponding point in the next. It is evident that this may be measured in two ways, either along the arc, "arc pitch," or straight from one point to the other, "chord pitch." Some engineers use one, and some the other. It is, of course, in wheels of a small number of teeth that there is much difference between the chord and the arc. It makes no material difference which is used, provided that it is clearly understood by all concerned whether "arc" pitch or "chord" pitch is intended in any particular case. In most engineers' pocket books there are tables giving the diameters of wheels of different numbers of teeth when "chord" pitch is employed. Or they may be found trigonometrically.

DIAMETRAL PITCH.

The number of teeth per inch diameter is called diametral pitch by some leading authorities, *e.g.*, Messrs. Brown and Sharpe, of Providence, U.S.A. But diametral pitch, according to other authorities (as Messrs. Musgraves, of Boltón ; and Professor Unwin), is the inches, or parts of inches of diameter per tooth. As for example, two teeth per inch diameter would be half-inch diametral pitch, and one-half tooth per inch diameter would be two inches diametral pitch. If, however, instead of using the words diametral pitch, which are employed in a different sense by different persons, we specify the number of teeth per inch diameter, no confusion can result. If this system of the relation of the number of teeth to the diameter is made the leading principle, it is easier to work to (when one is accustomed to it) than the system of circumferential pitch, and the wheels will be of even dimensions as to the diameters of their pitch circles, and the centres of their shafts will be of even dimensions apart. This diametral system is sometimes used for large gearing, and its use in that direction is extending. It is generally employed for small gear wheels, such as are used for light machinery. I will give a few sizes of corresponding circumferential or circular pitches, and the number of teeth per inch diameter :—

Number of teeth per inch diameter ...	3	2	1¼	1	¾
Circumferential pitch in inches ...	1·0472	1·5708	2·5133	3·1416	4·1888

BREADTH OF TOOTH.

The breadth or "face" is, usually, in ordinary mill gearing, from twice to four times the pitch. About three times the pitch is a very usual proportion. Of course, having a toothed wheel broad diminishes the wear on the teeth, other things being equal; but in ordinary cast wheels, if the wheel is broad, then each tooth is long (as measured across the wheel) and inaccuracies of workmanship often prevent the wear from being equally distributed. This does not apply to cut teeth. When wheels have been at work together a considerable time they usually get to a good working surface, becoming straight all across, and so far the wear of working improves the teeth as respects their straightness; but wear in working will not improve the shape of the teeth in respect of their curves.

HELICAL GEARING.

Even when the teeth of wheels are made of the best shape possible, it is found that the uniformity and steadiness of motion are promoted by the teeth coming into contact as rapidly as possible one after another. With ordinary wheels this means that the pitch must be small. But when the pitch is small the power transmitted is necessarily small, because the individual teeth are weak. To overcome this difficulty, Dr. Hooke invented stepped spur wheels, that is to say, the wheel was, as it were, cut into slices by planes at right angles to the axis, and then these slices re-united, but the teeth slipped back. For instance, if the pitch of the wheel was four inches, and it was divided into four slices, spaced equally apart, so that the slices should come into gear successively, then a smoothness of motion, equal to that of wheels of one inch pitch would be obtained, with the strength of four inch pitch. If the slices be supposed infinitely numerous, then the front of the tooth intersects the pitch cylinder in a helical line, and we get a "helical" spur wheel. When accurately constructed, there is always continuous steady contact of the teeth in gear. But the teeth, being "on the slant," an endlong thrust in the direction of the shaft is set up, and this is, of course, prejudicial. To counteract this, the wheels are made of combinations of right-hand and left-hand helices, thus forming the well known Double Helical Toothed Wheels. The skill of our engineers and mechanics is well shown in the construction of double-helical wheels, both spur and bevil These can be procured, as is well known, as ordinary articles of manufacture. Helical wheels, well made, work very smoothly and quietly. The form of tooth is a very strong one, and the teeth are not so liable to be broken as ordinary straight teeth. To enable the right-

handed and the left-handed halves of the helix, each to take their proper share of the work, it is desirable that one of the wheels should be arranged so as to have a little end play.

SHAPE OF THE RIM AND ARMS.

The ordinary rules for proportioning castings should be carefully attended to in the case of large toothed wheels. That is to say, the metal should be distributed as evenly as possible so as to avoid setting up initial strains in the cooling of the casting. In the cases which still sometimes occur, where a fly-wheel is also a spur wheel, it is best to make the teeth on separate segments, securely attached to the fly-wheel. This method also has the incidental advantage that if a few of the teeth are broken a new segment or segments can be provided. The circumference of the fly-wheel should be turne , and the segments bored to fit.

The arms of large spur wheels are usually cruciform in cross section, or else H shaped. Sometimes in very large wheels they are box section. The arms of bevil wheels are usually T shaped.

The number of arms generally is—

For wheels up to 4 feet diameter		...	4 arms
„	from 4 ft. to 8 ft. diameter	...	6 „
„	from 8 ft. to 16 ft. diameter	...	8 „

For wheels revolving rapidly it is a good practice to fill in the spaces between the arms with boarding, or sheet metal, so as to avoid churning the air.

I need not go into the details of securing toothed wheels to their shafts, further than to say that the hubs of wheels should be well strengthened in those parts where keyways have to be cut.

METHODS OF MANUFACTURE.

The great majority of toothed wheels used for the transmission of fairly large amounts of power have their teeth cast. The moulds of the teeth may be made by one of three methods—

1. By an entire pattern of the wheel.
2. By the use of a corebox by which a few teeth are moulded, and a succession of these moulds placed circularly so as to form a complete ring.
3. By means of a moulding machine, in which a pattern is made of a few teeth, and that is carried round a central spindle, making a mould for all the teeth in the wheel successively.

Method No. 1.—This is the method formerly always adopted, but it has two great disadvantages, the pattern is very expensive to make, and however well seasoned the wood may be, yet, owing to the varying

hygroscopic conditions to which the pattern is exposed, sometimes in damp moulding sand, and sometimes in a dry and warm store, it is almost sure to become distorted to a greater or less extent, and then the casting is not accurate. In pattern-moulded teeth also, a slight taper has to be given, to effect the withdrawal of the pattern from the monld. The wheels cast thus should, theoretically, be placed to gear with the draft of the teeth in opposite directions; but this is often not attended to, and then the teeth bear more at one end than the other.

Method No. 2.—The "corebox" method is considerably cheaper in pattern making, but it requires exceeding accuracy in the moulding. As the corebox is so much smaller than a whole pattern for a wheel of the same size there is not the same likelihood of distortion in the corebox, from hygroscopic conditions, but the chance of inaccuracy of workmanship in the placing of the cores around the circumference of the mould is the same in every wheel that is moulded.

Method No. 3.—Machine-moulding is a most excellent method; but the machine must be a good one, and kept in proper order, so as not to become inaccurate by wear. Machine-moulding for toothed wheels was introduced by Messrs. P. R. Jackson and Co., of Manchester, about fifty years ago. The first machine-moulded wheel was exhibited in the Great Exhibition of 1851, and a few years after they were coming into comparatively common use.

(Here were shown lantern views 16, 17, 18, 19, 20, 21, 22, 23, 29, 29a, and 29b).

MACHINE-CUT WHEELS.

In many comparatively small machines there are toothed wheels in which the teeth are cut out of a solid rim, and for some purposes the teeth are cast approximately to shape, and then finished accurately to shape by the use of milling cutters or otherwise. Many of the older members of my audience will doubtless remember the old millwright of a former generation laboriously pitching and trimming a toothed wheel, that is to say, going over the whole of every tooth with a cold chisel and a file, bringing each to the accurate shape and dimensions required. The use of gear-cutting machines is nowadays largely extending, and I have here some photographs of such machines as made by eminent firms in this country and in the United States.

(Here were shown views 24, 25, 26, 27 and 28).

The machines made by these firms are more frequently employed for cutting gears of not more than $2\frac{1}{2}$ inches pitch. But gearing much larger than this is cut by machinery, and has been for a long time past. At the Centennial Exhibition, held in Philadelphia, United States, a quarter of a century ago, the whole of the power of a pair of large Corliss Steam Engines, giving motion to the machinery in the immense

Machinery Hall, was distributed by means of large machine-cut gear wheels. The main spur fly wheel was 30 feet in diameter, and weighed 56 tons. Its circumferential speed was 3,400 feet per minute. The teeth were on segments as previously described. The bevel wheels, to alter the direction of motion of the main shafts were also machine cut, they were four inches pitch, and five feet six inches diameter. Their circumferential speed was 2,250 feet per minute.

I have seen it stated on good authority that a spur wheel in America, 30 ft. dia., 5 ins. pitch, 24 ins. wide, was running at a circumferential speed of 4,700 feet per minute.

The use of cut-toothed wheels of large size and to transmit large amounts of power is extending. I may mention that the R. D. Nuttall Co., of Pittsburg, Pennsylvania, United States, make cut gears exclusively, from quite small sizes up to thirty feet diameter, and 66 inches face. Messrs. Scott and Hodgson, of Guide Bridge, near Manchester, cut wheels of any weight, and up to 26 feet diameter. I have here two lantern views, Nos. 30 and 31, showing a spur wheel and pinion by the latter firm. The spur wheel is more than 17 feet diameter, seven inches pitch and 30 inches wide. The pinion is about four feet three inches diameter, and of forged steel. All the teeth are cut. The weight of this wheel and pinion is about forty-four tons.

The Buffoline Noiseless Gear Co., of Levenshulme, Manchester, make machine-cut wheels up to 11 feet diameter. Probably there are other engineers who have laid themselves out for this class of work, but I mention some who have kindly sent me information specially for this paper.

Some engineers hold the opinion that if wheel teeth are cut, they wear faster than teeth that are moulded, because in the latter case there is a hard skin on the surface of the casting. This may be so, but with cut wheel teeth the wear is so evenly distributed that the teeth get a very fine and hard surface if they are properly attended to. There is not in many cases such long experience of heavy cut wheels as of moulded ones. I have, however, heard of a large cut wheel made twelve years ago, that is running now and giving every satisfaction.

MATERIAL.

Large toothed wheels are always made either of cast-iron or of cast-steel, the latter material is by far the stronger, and now that the methods of dealing with it are better understood than they were when the use of this material was first introduced, trustworthy castings can be and are, produced. But even now it is difficult to ensure as great accuracy in moulded cast-steel wheels as in cast-iron ones.

In ordering steel wheels it is well to exercise caution and to procure them from firms that have made a speciality of this kind of work.

By far the larger number and weight of toothed gearing in use at

present is made of cast-iron, and the nature of this material, and the precautions to be adopted in dealing with it, are so well understood, that good cast-iron wheel castings can be procured in most places where iron foundries exist. For special purposes other materials are used, as forged steel where very exceptional strength is required, solid forged iron where extreme toughness is wanted, phosphor bronze or gun metal for extreme smoothness of action, and wooden teeth or raw hide, or similar substances for transmitting power silently in very quick running machinery.

SPEED AND POWER TRANSMITTED.

With respect to the speed at which toothed gearing is, and may be run, it very generally happens that other considerations than those of the best or most economical speed have to be taken into account, as these considerations exercise the most weight in the determination of the speed. Take for example a train of wheels in a mill for rolling brass or copper. Here the most important consideration is the speed at which each pair of rolls should be driven, and the wheels have to be made amply strong enough to drive the rolls at the proper speed. But when the transmission of power to quick running shafting is the object to be accomplished, it becomes desirable to know how fast toothed gearing may be safely driven, because, if the gearing is run at a high rate of speed it may be, other things being equal, made much lighter than otherwise, thereby effecting much saving in first cost, and, to some extent in running charges. The following may be taken as the greatest speeds at which the different descriptions of toothed wheels may be safely run. The speed is that at the pitch circle, in feet per minute. In bevel wheels the pitch circle is taken as that at the largest diameter of the wheel :—

Ordinary Cast-iron Wheels	...	1800	feet per minute.
Helical Wheels	...	2400	,,
Mortice Wheels	...	2400	,,
Machine-moulded Cast-iron Wheels		2000	,,
Machine-moulded Steel Wheels	...	2500	,,
Machine-cut Wheels	...	3000	,,

To run well at these speeds the wheels require to be very well made and balanced, and to run very truly. Messrs. P. R. Jackson and Co., of Manchester, inform me that they have had machine-moulded toothed wheels running over 4,000 (four thousand) feet per minute; but I I think this must have been a very exceptional case, and probably few engineers would care to run wheels at so high a speed. Unwin gives an instance of even a much higher speed, namely, 5,760 feet per minute for cast-iron wheels, but though the wheels were exceptionally well made they broke up, apparently from centrifugal force. Musgraves, of Bolton, have published a table of powers at speeds up to five thousand feet per minute, both for cast-iron and steel. High speeds should only

be attempted, in my opinion, with cut gears, and under the very best conditions.

STRENGTH OF TOOTHED WHEELS.

By this, I mean the size of pitch and face for transmitting given amounts of power. The face, or breadth of a toothed wheel is usually about three times the pitch. In calculating the strength of teeth of wheels it should be considered whether the kind of mechanism and the conditions of working are ever such that the whole strain may come on the end of one tooth. This is the worst case that can happen, the tendency then is to break the corner of the tooth off, and, to be safe, the tooth must be strong enough to resist this. In machine-cut teeth the strain is transmitted equally across the whole width of the tooth, and this is the best condition of working. In ordinary practice, the conditions would usually vary between these best and worst cases; but when the wheels are new, if they are ordinary cast wheels, they should be run very carefully, and with a light load at first, so as to ascertain if there are any lumps on the teeth, which, if existing, should be filed down, so as to distribute the wear with some approach to evenness.

It is an old rule, to secure durability (with cast-iron teeth) that the pressure on a tooth in contact should not exceed four hundred pounds per inch in width. Authorities differ as to the safe pressure at the pitch line, and very much depends on the local circumstances as affecting vibration and shock, besides the material of the wheel and the mode of manufacture. Musgraves, of Bolton, give the following rule:—Square the (circular) pitch in inches, and multiply by the width of the wheel in inches and by the speed in feet per minute at the pitch line, and then divide by one thousand for cast-iron, or by six hundred and twenty-five for steel. This will give the horse power that may be transmitted. I will tabulate below the power transmitted by a cast-iron spur wheel of four inches (circular), pitch and twelve inches breadth, running at a speed of one thousand feet per minute at the pitch circle, according to different authorities:—

Adcock	140	horse power.
Four hundred pounds per inch rule (see above)	145	„
Nystrom	155	„
Unwin (moderate shock)	186	„
Musgrave	192	„
Molesworth	200	„
Kempe	252	„
Unwin (no shock)	290	„
Mean of the above eight authorities	195	horse power.

The figures in this table take into account the width of the teeth, but the higher figures are on the assumption that the teeth bear fairly all across the face. As before stated, the above figures are for cast-iron wheels. Steel wheels will transmit much more power on account of their greater strength, say from thirty to fifty per cent. more.

I have now given a *resumé*, necessarily brief, of a very extensive and interesting subject, and though I do not claim originality, yet I hope that I have been able to bring before your notice some considerations of which some of you were not aware, and which, perhaps, may prove of value to you.

In the preparation of this paper, I have been assisted by several firms who have sent me photographs and other illustrations of their manufactures and these I have shown you, but there are many other firms who make similar machines and wheels, and in the selection of some firms I imply no disparagement of others also of high standing.

I will conclude by showing you a few lantern slides taken from drawings of large gear wheels, spur and bevel, made by Messrs. Buckley and Taylor, of Oldham.

I must express also my thanks to my friend Mr. Alexander E. Tucker. for his kindness in the preparation of the lantern slides.

LIST OF LANTERN SLIDES.

1	Illustration of Discs in contact		These 4 figures are on one sheet.
2	Four-armed Star Wheel		
3	Continuous motion (uniform)		
4	Motion not uniform		
4A	Involute Teeth.		
5	Unwin's Method of Drawing Wheel Teeth.		
6	Kempe's and Nystrom's	do.	
7	Ohren's	do.	
8	Willis's	do.	
9	Relative Thicknesses of Teeth.		
10	Relative Lengths of	do.	
11	Half-teeth.		
11A	Increasing Pitch (few teeth).		
11B	Increasing Pitch, Whole Wheels.		
12	Buckley and Taylor's Patent Steel Rims for Pinion Wheels.		
13	Do. do.	Patent Spring Bevel Wheels.	
14	Do. do.	Elastic Spring Pinion Wheels.	
15	Do. do.	Fly Spur Wheel and Pinion.	
16	Do. do.	Plan of Patent Combined Table and Arm Wheel Moulding Machine.	
17	Do. do.	Sectional Elevation, do. do.	
18	Do. do.	Plan of Improved Table Wheel Moulding Machine.	
19	Do. do.	Elevation do. do do.	
20	Do. do.	Perspective View of do. (photo.).	
21	Whittaker's Floor Wheel Moulding Machine.		
22	Do.	Table Wheel Moulding Machine.	
23	Whitmore's Single Stand Moulding Machine, for small wheels.		
24	Brown and Sharpe's Automatic Wheel-cutting Machine.		
25	Smith and Coventry's	do. do.	
26	Do. do.	Bevel Gear Planing Machine.	
27	Do. do.	Robey and Smith's Patent do. do.	
28	Do. do.	Sixty-inch Wheel Cutting and Dividing Machine.	
29	P. R. Jackson and Co., Group of Wheels (Machine Moulded).		
29A	F. H. Lloyd and Co., Group of Machine Moulded Steel Wheels.		
29B	Do. do.	do. do.	
30	Scott and Hodgson, Cast-steel Spur Rim with Cut Teeth.		
31	Do. do.	Spur Wheel, 17ft. diam., with Pinion, Steel, Cut Teeth.	

THE DISCUSSION.

Mr. Jno. W. Hall: I am very pleased to have been here this evening to hear Mr. Thornbery's paper. It is a question on which Mr. Thornbery has had a great deal of experience, and he is, therefore, well qualified to address us. I have listened to the paper with considerable gratification. I think the illustration he gives of the four arms is the neatest explanation I have yet seen of the necessity for forming the teeth of wheels by some rule other than pure guess work. With regard to adopting any particular method of forming teeth, there are several considerations which have to be taken into account, and the first is that the method shall be one readily understood by the workman, so that a highly skilled man to set out the wheels shall not be a necessity The cycloidal tooth is troublesome to produce, as Mr. Thornbery says, because it requires a good deal of setting out. A good many years ago, when managing a works where we made a great many toothed wheels, I had to settle what type of tooth we should adopt as our standard. I tried Ohren's method first, because it was a method which any ordinary pattern maker could understand, and secondly because it is a method which does not produce narrow flanks to the teeth of small pinions. I found it so satisfactory, and so easy to use, that we adopted the plan exclusively, and we never had any complaint or trouble with it, although we made wheels whose pitch line ran up to nearly 2,500 feet per minute, just as cast, with merely ordinary dressing. I am very pleased to find that Mr. Thornbery has put his foot upon that popular fallacy, that if the teeth of wheels are properly formed they roll on one another instead of sliding. Such a statement is quite a mistake, for as a matter of fact no shape of tooth can do that. It is not as generally known as it should be, that given a wheel having teeth of any form you like within reason, a second wheel with any desired number of teeth can be constructed, which will work with it with an absolutely correct velocity ratio, and that the forms of the teeth of the second wheel can be obtained from those of the first in a very simple manner. Cut the edges of two pieces of pine board to the correct radius of the pitch lines of the existing wheel, and of that you wish to run with it, putting a bradawl through each of the points representing the centres of the respective wheels, and stick these bradawls in your bench so that each of the boards can turn round its respective centre, with the curved edges of the boards in rolling contact. To ensure that they shall revolve in correct relation to each other, nail one end of a bit of tape (or better still, a clock spring, because this does not stretch), so that one half wraps round a portion of the pitch circle formed on each board. Fasten on to the board representing the existing wheel a template, whose edge is cut to the form of the existing tooth which it is required to match, raising this template, with a

little packing, sufficiently above the surface of the board to allow a strip of thin mahogany, nailed to the second board, to pass close below it. Then, keeping the tape always stretched tightly, move the boards into a series of positions which the wheels must occupy as they revolve, and with a fine pencil, held close to the edge of the tooth template, scribe a line on the strip of mahogany below it. The outline formed by all these scribed lines is a true "envelope" of the curve of the tooth of the existing wheel, and if the tooth of the new wheel is shaped to this curve, the existing wheel will drive the new one, or *vice versâ*, with absolutely correct velocity ratio.

This is a quick and simple method of forming a tooth to run correctly with another, whatever is the system on which the first is set out, or even if it is set out on no system at all. It is possible by this means to thicken up the roots of the tooth of a pinion to any desired extent and then construct a wheel to work correctly with it.

With regard to automatic tooth-cutting machinery, I certainly agree that machine-cut teeth are preferable, for the smoothness with which they run is remarkable, there being an entire absence of jerk. The use of machinery for cutting the teeth is a matter to which nearly all wheel makers are now paying attention. By the aid of modern machinery some very fine wheels can be cut nowadays; in Messrs. Krüpp's armour-plate mills, for instance, they have neck pinions with helical teeth cut out of solid steel forgings.

Mr. C. E. Bloomer: I have had particular pleasure in listening to the paper to-night, for Mr. Thornbery and I are old fellow apprentices, and possibly our interest in this subject was acquired during that time. I know it is a subject rather dear to his heart, and he must have spent very much time and thought in the preparation of the paper, and we are grateful to him for having consented to address us on the matter. It is a subject with which many of the members do not come in contact, and I trust the paper will have a tendency to cause them to take an interest in wheel gearing. I have on many occasions gone into mills and works and found a tremendous amount of noise going on, a good deal of it caused through the wheels not being well fitted together, in which case there is always a certain amount of backlash. Those difficulties will, I think, in the future grow less, for there are now machines for cutting these teeth perfectly true. I agree that engineers should have nothing but machine-cut teeth on their premises. There is one point I should like to ask Mr. Thornbery, and that is with respect to wood and iron. In the early days, engineers used to advocate that the driving wheel should be of iron, and the teeth in the driven wheel of hard wood, such as hornbeam. I know from experience that wheels of this description run very smoothly—in fact after they had been running a little time you could go into the engine house and hardly

know there was a pair of wheels running. The subject is well worth the attention of all who have anything to do with machinery.

Mr. L. D. Thomas: Mr. Thornbery has brought before us a subject which has been discussed among engineers ever since I can remember. He has dealt with it in a very plain, simple, and practical manner. Of course we do not all agree with everything in the paper, or see everything in the same light; but the paper as a whole is a very good one. Various forms of teeth have been brought before us, including Unwin's; but that is a form of tooth I always abhorred. It is not a well shaped tooth, and in my opinion it is very weak at the root. The cycloidal teeth, I think, are the best. That teeth do not "roll" on each other, I agree. The term probably arose from some confusion of terms. With regard to wheel-gearing production, practice and experience have taught our engineers much more than they knew in days gone by. A heavier class of work can be turned out than formerly, and there have been great improvements, especially in gear intended for rolling mills. Some years ago it was not possible to roll the large masses of steel that are now produced. Rolls of 18 or 20 inches diameter were then considered large; now we have them up to 36 inches diameter, and this requires much greater strength in the toothed gear. Double helical gearing was, I believe, invented by a Staffordshire man, who was born at Tipton and emigrated to America while he was young. Mr. Thornbery says the arms of spur wheels are usually cruciform in cross section, or else H shaped. The H shaped arm is also a Staffordshire invention. It was, I believe, patented by a firm in the neighbourhood of Bilston some years ago. There is nothing in the paper to cause any difference of opinion, and the only thing we can do is to praise its author and put his recommendation into practice.

Mr. Thornbery: I thank you for the kind manner in which you have received my paper. I had some misgivings as to whether it was a proper subject to bring before you; but I hope I have been able to adduce some considerations that may be useful. Mr. Hall mentioned Ohren's method, and it seems he has had considerable practical experience with it, so I think you may take his opinion upon that point as very good and worth following. The method I have generally adopted is Professor Unwin's. It does, for certain sizes of wheels, give a weak root, but if a portion of the circle is taken properly I don't think there is much fault to find. The method mentioned by Mr. Hall of forming a tooth to gear with any existing tooth is very neat; I know a method myself, but I think Mr. Hall's is better. Certainly machine-cut teeth are being very largely used now in works, but it was news to many of us to find what very large cut gear was being employed for transmitting large amounts of power, though I have not seen many of these big cut teeth in this district. With respect to the point Mr. Bloomer mentioned as to iron and mortise wheels, I think the practice is sometimes to have the driver

mortised and sometimes iron. Years ago every first-class flour mill used to be driven by mortise wheels, actuated by iron wheel gearing. This was when millstones were used. Sometimes the large wheel was the mortise and sometimes the small one according to convenience. I like Unwin's method for forming the shape of teeth, because it is the one I am most familiar with, and I can see exactly the development of the curve; you can see why the circular work which you get by the method is a near approximation to the mathematically correct curves. Other methods produce a correct form, but they do not show *why* the form is correct. I daresay Mr. Thomas is right about the "rolling" fallacy. It certainly arises from some confusion of terms; someone must have got the idea that the teeth rolled on each other. That is quite a mistake. Mr. Thomas gave us an interesting piece of information when he said he thought the inventor of the double helical teeth was a Staffordshire man. Could he remember his name?

The "H" shaped arm is a very good shape. I became familiar with that form of work first in connection with machine-moulded wheels. Perhaps I have told you in my paper of one or two facts of which you were not previously aware, or perhaps not; but all I have put before you *are* facts, and there is very little ground for controversy; though I should have liked some of the members to have given their opinions as to the respective merits of forming teeth by cutting or by moulding, and especially as to whether removing the skin *does* reduce the life of the wheels much.

Mr. Walter Jos. Flavell: One of the most important points dwelt upon by Mr. Thornbery, is the shape of the teeth. The system invented by Professor Willis, with the aid of the Odontograph, and other methods mentioned, are undoubtedly good, and well suited for work where the load is continuous and the strain does not vary greatly. But in iron and steel works practice, where the wheels are subject to occasional heavy shocks and strains, none of the systems mentioned to-night seem to give exactly the shape of tooth that is required. Most of the systems will give a very good tooth, if the wheels which work into each other are of the same size, or nearly so; but if the driver is working into a spur, of only about one-fourth or one-fifth of its diameter we find that by following out our system for arriving at the shape of teeth, that the spur has a very small area in the flank, or root, and is unable to bear the backlash which has so much to do with the breaking of wheels in this district. More wheels are broken from this cause than by the actual work which they have to do. When wheels become worn, or are allowed to get too far out of gear, there is, naturally, a greater space between the teeth of the wheels than there should be, and when they are suddenly checked, the teeth, being worn or only working on the points are unable to bear the extra strain, and the result is a broken tooth or more. I believe

Mr. William Molineaux, late of the Caponfield Works, Bilston, was the first ironmaster to introduce double helical wheels in this district.

Mr. L. D. Thomas : As I previously stated, the individual who invented the helical form of tooth was born at Tipton. When about 12 years old he was taken to America by his parents, and worked there in a rolling mill with his father. The pinions connecting the rolls to the driving wheels were out of gear and caused much trouble. The lad, who was always trying some mechanical device or another, noticed the wheels and said he could remedy the defect. His father, by way of encouragement, chastised him for his presumption. The proprietor of the works heard of the lad's abilities as a mechanic, and of his statement that he could put the wheels right, and sent for the lad, who, after some persuasion, explained how he thought the difficulty could be overcome. The employer and his engineer worked out the lad's idea, and the result was the helical toothed wheel. The firm sent the lad to school for twelve months, and then to technical classes for a period. During that time they paid the parents the wages the lad would have earned had he been at work in the works.

On completing his technical course, the lad elected to be apprenticed to a clockmaker. In course of time he became the leading clockmaker in Philadelphia, and he designed and made the celebrated clock which was exhibited at the Philadelphia Exhibition of 1876.

The President : I have much pleasure in moving a vote of thanks to Mr. Thornbery. There is no doubt that many breakages are due, not to actual wear and tear, but to the manner in which wheels are put to do their work. If they are not kept true, they will not work correctly. I am pleased to hear that forged wheels are coming into more extended use, and I hope their employment will increase day by day. I have known Mr. Thornbery for some years, and I know he is considered a great authority upon this subject. We are much indebted to him, and we shall be very pleased to have a paper from him next session, upon some other engineering subject. I move that the best thanks of this meeting be given to Mr. Thornbery for his paper.

Mr. H. Parry seconded the proposition which was carried unanimously.

Mr. Thornbery suitably acknowledged the compliment.

ANNUAL MEETING.

The Annual Méeting was held at the Station Hotel, Dudley, on Saturday, April 26th, 1902.

THE PRESIDENT (Mr. WALTER SOMERS) was in the chair, and there was a large attendance.

The minutes of the last meeting were read, adopted, and signed.

Mr. Walter Flavell, of West Bromwich, was elected a member of the Institute.

The Secretary then read the Annual Report for the Session 1901-02, which was as follows:—

REPORT OF COUNCIL FOR SESSION 1901-1902.

The Annual Excursion took place on Friday, the 28th June, 1901, when 220 members and friends visited the Glasgow Exhibition.

Breakfast and Dinner were served in the Exhibition grounds. At dinner the President (Mr. Walter Somers) presided, having as guests the President, Secretary and several of the Vice-presidents of the West of Scotland Iron and Steel Institute.

One hundred of the party left Glasgow for home on the Friday night, the other one hundred and twenty remaining behind for some days longer.

The first ordinary meeting was held on the 28th September, 1901. At this meeting a resolution of sympathy with the American nation and Mrs. McKinley in the loss they had sustained by the death of President McKinley, was passed and ordered to be transmitted to the United States Ambassador. The President then delivered his inaugural address.

The second meeting was held on the 2nd November, 1901, at which Mr. Robert Buchanan read a paper on "The Foundry Cupola, and How to Manage it," and afterwards showed some lantern views of different types of cupolas.

The third meeting was held on the 23rd November, 1901, when Mr. Walter Macfarlane, F.I.C., delivered a Lecture on "Modern Steel Making," which was illustrated by a large number of lantern views.

The fourth meeting was held on the 14th December, 1901, when Mr. David Flather (Sheffield) read a paper on "Crucible Steel; its Manufacture and Treatment," and exhibited several specimens of crucible steel, etc.

The fifth meeting was held on the 1st February, 1902, when Mr. Ebenezer Parkes, M.P., delivered an address on "Foreign Competition," based upon his observations and enquiries during his recent visit to the iron and steel manufacturing centres of the United States of America on behalf of the British Iron Trade.

The sixth meeting was held on the 15th February, 1902, when Mr. S. J. Thompson read a paper on "The Dürr Water-tube Boiler," and illustrated it by means of a number of lantern slides, a collection of fittings, and a working model of the boiler in operation.

The seventh meeting was held on the 12th April, 1902, when Mr. W. H. Thornbery, of Birmingham, read a paper on "Wheel Gearing," which was illustrated by a number of lantern views of moulding machines and wheels, and machines for cutting wheel teeth.

All the meetings have been well attended, and the papers and addresses have caused a considerable amount of interest and discussion.

The following have joined during the year :—

Honorary.—Maurice Lees, Alexr. V. Perry, and J. G. Reay.

Ordinary.—Horatio Booth, Robert Buchanan, Harry Burford, T. J. Dudley, J. W. Growcott, T. W. Moseley, Jacks, Robert Johnson, John Keeling, T. R. Knowles, F. N. Macartney, Daniel Meese, H. Mensforth, Fredk. J. Millard, Frank Moore, Percy Mountford, Joseph A. Parker, Harold Piper, John E. Pugh, Philip Robinson, T. Lawrence Rose, David Rushworth, A. Lynn Scotson, W. S. Smith, William Somers, Henry Taplin, S. J. Thompson, Charles H. Wall, E. J. Whitehouse, Edward Wright, and Charles R. Yates.

The following have left during the year :—

Honorary.—A. V. Perry.

Ordinary.—R. W. Bradley, W. H. Bostock, W. H. Greenwood, Godfrey Melland, Jos. Grice, Richard Hall, J. A. Hatfield, G. C. Lamb, W. H. Perry, John Skidmore, R. M. Tolley, J. E. Payne, J. F. Sample, G. A. Millward, P. E. Spragett, and J. P. Walton.

Died.—Edward Fletcher and Herbert Whitehouse.

The present state of membership is as follows :—

	Honorary.		Ordinary.
No. of members in April, 1901	53		168
Joined during the year	3		30
	56		198
Died		2	
Left		4	18
Resigned	1	6	
Struck off		6	
No. of members in April, 1902	55		180

Total number in April, 1902	235
Do. do. 1901	221
Increase	14

The finances continue to improve very satisfactorily, as will be seen from the Balance Sheet to be presented by the Auditors, the cash balance on 31st December last being £126 5s. 8d.; an increase of £33 17s. 8d. during the year.

With respect to the Excursion during the coming summer, the Council have obtained permission from the Daimler Motor Co., Limited, and Messrs. Alfred Herbert, Limited, of Coventry, for the members to visit their respective works.

For the Council,

WALTER SOMERS, President.

WILLIAM H. CARDER, Secretary.

Dudley, 23rd April, 1902.

Mr. James Raybould then read the Balance Sheet for the year ending 31st December, 1901.

(The Balance Sheet will be found on page 164.)

On the proposition of Mr. Parry, seconded by Mr. Moses Millard, it was resolved, that the Report and Balance Sheet be received and passed, and printed in the "Proceedings" for the Session.

Professor Thomas Turner said he had a resolution to propose with reference to the office of President. It had been their custom to appoint as President for the year the Vice-president who had served during the past year. In the present case their Vice-president had left the district, having received an appointment quite away from Staffordshire. The result was that the Council had had to consider carefully what should

be done. They wanted someone who had had experience of the work, who was acceptable to all the members, and who had a knowledge of the trade of the district. He was quite sure no one united these qualities better than Mr. Somers, and, he therefore begged to move that Mr. Walter Somers be re-elected president for another year.

Mr. H. PARRY seconded, and observed that when he moved the appointment of Mr. Somers twelve months ago, he predicted a successful year for the Institute and also a great deal of pleasure for Mr. Somers. No one who had read the Annual Report could fail to be impressed by the character of the year's work, and no one who had seen Mr. Somers in the chair conducting the meetings would doubt the wisdom of re-electing him.

The resolution was put to the meeting by Professor TURNER and carried with acclamation.

Mr. SOMERS: I thank you very much for the honour you have done me in re-electing me as your President for a second year, as it affords me some assurance that what services I have rendered have given you a certain amount of satisfaction. I hope the coming year will be even better than the one which is now closing. I feel quite sure I shall have the hearty assistance of every member of this Institute in carrying out the work.

THE CHAIRMAN next proposed the election of Mr. William Brooks as Vice-president, observing that that gentleman had always taken a great interest in the Institute, and expressing the belief that he would at all times render the Institute every service which a vice-president should do.

The resolution was warmly supported by Mr. W. B. RUBERY, and carried unanimously.

Mr. BROOKS said he thanked them very much for the honour they had done him, and he would endeavour to fill his predecessor's place to the best of his ability.

Mr. PIPER was re-elected Treasurer on the proposition of Mr. PARRY, seconded by Mr. L. D. THOMAS.

Mr. W. H. CARDER was also re-elected Secretary on the proposition of the PRESIDENT, seconded by Mr. YEOMANS, and supported by Mr. PARRY.

THE SECRETARY announced that there were six vacancies on the Council.

On the proposition of Mr. JOHN FELLOWS, seconded by Mr. JOHN KEELING, Messrs. Alfred Cookson, David Evans, Joseph Brown, W. J.

Foster, J. Donechay, and John Bate were elected to fill the vacancies; and it was agreed that the Council for the ensuing year should consist of Messrs. Thomas Ashton, John Bate, Joseph Brown, Alfred Cookson, J. Donechay, David Evans, W. J. Foster, Jno. W. Hall, Walter Jones, Richard Lythgoe, Moses Millard, Henry Parry, Thomas Pasfield, William B. Rubery, Harry Silvester, Leyshon D. Thomas, Harry B. Toy, Alexander E. Tucker, Thomas Turley, Professor Thomas Turner, and William Yeomans.

Letters from Messrs. Alfred Herbert, Limited, and the Daimler Motor Co., Limited, of Coventry, having been read, after some discussion it was resolved that the Excursion this year be to Coventry, in the third week in July, and that the Council be empowered to make all arrangements necessary.

A vote of thanks to the President for his services during the year was moved by Mr. L. D. THOMAS, seconded by Mr. MOSES MILLARD, and carried unanimously.

In acknowledging the vote, the PRESIDENT said he hoped there would be some very interesting papers during the coming Session, that the members would continue to attend the meetings in good numbers, and that the younger members especially would come to the meetings prepared to take part in the discussion. The continued usefulness of the Institute depended, to a great extent, upon the thoroughness with which the members studied the papers sent to them prior to the meetings at which they were read, and their consequent ability to discuss the papers and thus contribute to the common stock of information.

THE ANNUAL DINNER.

The Annual Dinner was held subsequently at the Station Hotel, when the President (Mr. WALTER SOMERS) presided over a large attendance. The toast of "The King" was honoured with much enthusiasm.

Professor TURNER, in proposing the toast of "The Iron, Steel, and Coal Trades of Staffordshire," said: I have had to take this toast at short notice, but no one could take more interest in the welfare of the district than I do. Our district has been threatened on several occasions—three occasions almost within my own recollections—with practical extinction; yet the district is still thriving and doing good work. It was expected shortly after Sir Henry Bessemer introduced his steel process that the wrought-iron trade of Staffordshire would be stopped. Then afterwards, when big works like Nettlefold's were taken to the coast, it was thought that our inland trade would go. And again, last year, when we suffered severely from American competition. We had American iron and steel sent 3,000 miles across the ocean into this country. We have surmounted all these difficulties, and, for the time being, even American competition has ceased. The population of our district is increasing, our towns are becoming not only more populous but better lighted, better built, more wealthy, and more creditable in every way to the inhabitants. The members of this Institute, some of whom I have had the pleasure of knowing for twenty years past, certainly do not appear to have suffered very much from this process of extinction or diminution. They seem to have improved in many ways in spite of the difficult circumstances through which the district has had to pass. Now I have to speak particularly of the coal and iron trades and not of the district as a whole; but the welfare of the district is so intimately associated with the welfare of the coal and iron trade that you cannot separate them. Where should we be apart from the coal trade? Coal means heat, and heat means energy in every form; and it means even life itself. Every article we wear is made by machinery which is driven by power derived from coal. The very life and comfort of our homes in winter time depends upon coal; indeed, almost everything about us is dependent on the fuel which is raised in our midst. Our very life, therefore, depends upon the industry which is carried on amongst us. I welcomed with much pleasure the tax put upon coal last year, and, personally, it has been a regret to me this year that the Chancellor of the Exchequer did not add to the export duty on coal and decrease the taxation in other directions. Why should we give the national life blood

to our competitors when our children will need that which at the present time we so lavishly send away? Coming to the iron trade, and speaking first of pig iron, one is glad to see that the prices are maintained and that there is a good demand tor the production of the district. Of course we cannot expect to emulate the large productions of America, or even of our coast towns, simply because we have not got the same bulk of material with which to deal. The wrought-iron trade is also at the present time in a fairly healthy condition, and in the interests of manufactured iron makers I am glad to hear that in several branches we have extensions in the wrought-iron trade, and that in some directions in which steel was introduced, manufacturers have had to again take to wrought-iron, such as certain parts of ships, and also in regard to tin-plates, where some of the smooth steel is being replaced by wrought-iron. Now, if this is so, we can still hope for a long life for wrought-iron for a limited number of applications; indeed, we may yet find further applications for wrought-iron. But at the same time it must be admitted that, upon the large scale, steel is the metal of the future. There is no doubt the supply of steel in comparatively small quantities, ready for consumers to use, is likely to be the necessity of the future, and it is a need which should be supplied in this district. My interest in the coal and iron trades has been hitherto, as you know, theoretical and educational, but I venture to suggest to you that the connection between theory and practice in the iron trades of this district is very close at present, and is likely to be still closer in the future.

He coupled with the toast the names of The Mayor of Dudley (Mr. John Hughes) and Mr. James Roberts.

Mr. J. HUGHES (The Mayor of Dudley): I have some knowledge of the coal trade, and my experience is that it is a trade which is subject to great fluctuations. It is all up and down, and the coalowner is at the mercy of every consumer. In the old days, when the best iron in the world was made in this district, small shafts were sunk at the outcrop, and the thick coal was used for melting the pig iron as well as for making finished iron. In those days pack-horses were used, and I remember them being employed to carry the coal to the different residents in the neighbourhood. It required very little capital then to open a mine, as they sank little square shafts; but at the present day we have to go deeper down to find coal which is suitable for the manufacture of iron in this district. The thick coal of this neighbourhood is a pure coal, but I am sorry to say that there is very little of it left. We have only the remnants of former workings, and therefore, we raise fine slack, which all iron managers, and especially steel managers, constantly condemn. The science of chemistry has made such strides that every manager now knows exactly which kind of coal is best for his particular purpose. Formerly we not only had thick coal but also plenty of ironstone in our own neighbourhood, and nobody produced better

material. Unfortunately for this district, what little ironstone is left cannot be worked at a profit. The cost of labour has so advanced that we cannot get it to make pigs with at a price which is remunerative to the manufacturer. I am pleased to be associated with the managers of this district, and I hope that in a short time we shall be raising in this district plenty of thick coal, of a quality that will help the managers to keep up the reputation of South Staffordshire for iron manufacture. As to the ironstone, if we cannot get cheap labour, we must put in machinery. I remember Mr. Blackwell trying experiments for Sir Henry Bessemer (who was then plain "Mr." Bessemer). The great steel inventor was in very low water at that time—between 1850 and 1855. He came to Russell's Hall, and Mr. Blackwell, who was one of the cleverest ironmasters Staffordshire has ever had, tried several experiments for him. Blackwell died in a very curious way and under painful circumstances; but if he had gone on working hand in hand with Bessemer, he and Bessemer would have both died millionaires; but Samuel Holden Blackwell spent all his money, as well as his time, in trying to improve the iron trade of Staffordshire.

Mr. James Roberts also replied to this toast. He said: We have, as usual, had a good speech from Professor Turner, and I think you will allow me to congratulate him, on behalf of the Institute, upon being appointed Professor of Metallurgy in the Birmingham University. With regard to the Mayor's remarks, it is true I am still a young man, but I should be pleased if the coalowners could give us that thick coal they speak about at the price they now charge us for slack. The old days may possibly have been the palmy days of the coal trade, but pardon me if I doubt very much, as a user of coal, whether those times were any better for the coal producers than the present day. Well, with reference both to coal and iron, we have gone through both rough and smooth times, and we must go on and make the best of it. We have had to face American competition, and yet we find that they are now coming into this district to buy pigs to be sent to America. There is something soothing in that reflection because American competition is stopped when the American home demand is sufficient to consume their production. At the same time, we must not forget that this cessation of competition is only likely to be temporary, and that we shall have to face a renewal of it before long. It is better, therefore, to look things squarely in the face and not bury our heads in the sand like the ostrich. The Americans are preparing for an enormous output of iron. This year it is estimated at 18,000,000 tons, and next year I venture to say the output will be considerably larger. The question is, how much can they use in their own country? In Great Britain we have 36,000,000 of people approximately, and we use about £10 worth of iron and steel per head per year. In America they have some 74,000,000 of people, and ther wants will grow in proportion as their population grows and their wants will grow faster than our own. But then they have what we

have not. They have enormous tracts of country where they have lime and ironstone all contiguous. A friend of mine told me this week he was developing 32,000 acres with enormous beds of coal, best Bessemer ore, and also his own limestone. Well, there is only one way in which we can hope to live, and that is to be prepared. We have now before us, I believe, a period of two or three years in which we shall have comparatively little competition from America. In those two or three years we shall have to put our house in order and get ready for renewed competition. We must spend money like the Americans do, and we can only do that by effecting combinations such as will give us control of large amounts of capital. Small concerns are doomed. We must look to huge concerns to meet the competition in the big lines in which competition comes. We see this tendency in the amalgamation recently effected by Guest, Keen, and Co., and in those which are now taking place in the North of England and Scotland. When our English combinations get control of large amounts of money they will be able to put down large plants. In this country we have several steel works which are rolling girders, but when I tell you that last week I saw one single mill on the Continent turning out 50 tons of 14-inch girders per hour, you will see that we are still a long way behind. This mill is now at work at Differdange, Luxemburg. It is a patent mill, built by Mr. Henry Grey, one of Mr. Carnegie's old managers. The matter is of particular interest to this district, since Mr. Grey was originally a Dudley man, who left here as a youth. That mill is turning out girders with flanges 12 inches deep. They have undertaken to turn out 1,000 tons of beams in 24 hours out of that mill. Now most of you are practical men, and if you will ask yourselves the question what that means in respect to the cost of production, you will readily see that we have to meet some competition in the future. Of course our American and Continental competitors have carriage against them, but a mill turning out so cheaply as that mill can, will always be in a position to hold its own in the worst possible times. That is what we want in this district, namely, to get large plants and combination. Managers should urge this, and push it, and see if we cannot hold our own when the black days come.

Alderman Grainger proposed the toast of "The Institute," and observed that societies like this must quicken trade. He went on to dwell upon the desirability of promoting close relations between trade and technical education. Educationally we were behind other countries. He commended the Government's education scheme, and trusted facilities would be offered for students to make their way from the elementary schools to the universities.

The President replied for the Institute, and observed that the Institute was founded 40 years ago, and he remembered going to the first meeting. He believed it was the oldest society of the kind in Great

Britain. The Institute was undoubtedly doing a great work, and he wished that some of the large employers of labour in the district would recognise that fact more than they did at present. It was gratifying to find that it was a Dudley man who laid down the splendid rolling mill that had been referred to. The backbone of Staffordshire and Worcestershire was its coal and iron trade, and we must promote it by every possible means. One way to do this would be to improve the waterways from inland districts to the ports, which was a much cheaper system of transit owing to the lower wear and tear. If they had a good waterway, and steam barges going eight or ten miles an hour, they could send their iron from Staffordshire to London for 7s. 6d. per ton, and from Staffordshire to Liverpool for 5s. or 6s., and if those rates were offered them next week, many of them would be flooded with orders. At present the carriage of ore and other raw material from a distance into Staffordshire was very heavy, whereas if we had good canals it would be much less. In fact, in the matter of inland water communication we had made hardly any progress during the past hundred years. There was a great future for canals, and one of these days some progressive capitalist would form a powerful combination and make waterways right through Great Britain and work them by electricity. When this was done the rates would be so much less than those now charged by the railways that the manufactures of the Midlands would go east, west, north, and south.

The toast of "The Honorary Members" was proposed by Mr. Alexander E. Tucker, and responded to by Mr. Walter Jones, who wished the Institute would take up the matter of the Patent Laws, which in their present form meant nothing short of robbery. He also advocated the adoption of the metric system.

The toast of "The Vice-President" was proposed by Alderman G. H. Dunn in a humorous speech, in which he referred to Mr. Brooks' physical proportions.

The Vice-President (Mr. W. Brooks) responded in an equally genial tone. He concurred in what had been said as to the value of technical education, and advocated keeping abreast of the times if iron-making was to be carried on profitably, and urged the employment of high-class machinery and the best methods of work. He concluded by proposing the toast of "The Past Presidents," to which Mr. Silvester, Mr. Parry, and Mr. L. D. Thomas all responded.

The toast of "Our Guests" was proposed by The Chairman; and Mr. Walter Macfarlane responded. Mr. Macfarlane said he had always looked upon this district as being, so far as the iron trade was concerned, classical ground. The earliest blast furnaces were erected in this district; it was the native place of the famous Joseph Hall, of

on. The members of the Institute might be considered to be in ct apostolic succession to the great men of the iron and coal trades ie past—such men as Dud Dudley and others. We were at present he eve of great developments in the steel trade, and no one could where those developments would lead to, but in the near future it certain that something on the lines of the Talbot process would e to the front. Talbot was a native of the adjoining county of pshire and his father was a native of Brierley-Hill, so we were ently about to continue the best traditions of this grand old Black ntry.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

BALANCE SHEET,

FOR YEAR ENDING 31st DECEMBER, 1901.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance brought forward	92	8	0	By Expenses at Annual Meeting ...	6	11	6
,, Subscriptions	152	5	0	,, Printing and Stationery	68	17	7
,, Books and Papers Sold	15	10	9	,, Shorthand Notes	12	18	11
,, Interest on Invested Funds		13	9	,, Postages and Telegrams...	14	6	3
				,, Carriage and Sundry Expenses ...	3	17	7
				,, Rent...	8	0	0
				,, Secretary's Honorarium	20	0	0
					134	11	10
				Invested at 2½ per cent., £28 13 3; In Treasurer's hands, £97 12 5	126	5	8
	£260	17	6		£260	17	6

Examined with Vouchers and found correct this 24th day of April, 1902.

JAMES RAYBOULD, } AUDITORS.
RICHARD ROUND, }

VISIT TO COVENTRY.

On Wednesday, the 16th July, 1902, a party of about 130 members and their friends travelled by a special London and North Western train, which left Wolverhampton at 8-27 a.m., Birmingham at 9-20 a.m., and arrived in Coventry at 9-45 a.m. From the Station they walked to the works of Messrs. Alfred Herbert, Limited, where they were met by Mr. Harmer, Mr. Vernon, and other members of the Company's staff, who showed the party through the works, and gave whatever explanations were required as to the organisation of the works and the construction of the varied types of machines in use or in course of construction.

At the conclusion of the inspection of Messrs. Herbert's works, Luncheon was served in the King's Head Hotel.

Shortly after two p.m., several motor cars, sent by the Manager of the Motor Manufacturing Company, called at the hotel to convey members of the party to the Motor Works, which were reached at 2-30 p.m.

As the works of the Daimler Motor Company and those of The Motor Manufacturing Company adjoin each other, the party was divided into two companies—one going through the Daimler Co.'s works, while the other went through the works of The Motor Manufacturing Company. At about four p.m. each company changed and went through the works previously inspected by the other.

Both at the Daimler and the Motor Manufacturing Co.'s works every attention was shown to the members, several of whom availed themselves of the opportunity offered by the management of taking motor rides—under expert guidance—through the surrounding districts.

Dinner was served in the King's Head Hotel, at six p.m., the President having with him as guests Messrs. Oscar Harmer, P. V. Vernon, and A. E. Marston (Messrs. Alfred Herbert, Limited); and Messrs. George Iden and W. H. Thomas (of The Motor Manufacturing Co., Limited).—After the Loyal Toasts had been duly honoured, the President proposed "Our Guests," and expressed the thanks of the members for the opportunities afforded and the attention shown them during the day. He also announced that both the representatives of the Daimler Motor Company, who had been invited, were unexpectedly prevented from attending. Mr. Harmer and Mr. Iden responded, and also dealt with the responsibility resting upon those who produced the material which ultimately formed part of the complex machines with which each of them had to deal.

The party left Coventry for home at 8·5 p.m.

The following letterpress formed part of the Programme for the day:—

COVENTRY.

Coventry—in Domesday Book *Couentrev*—is a place of great antiquity, 18 miles S.E. of Birmingham, and 85 miles N.W. of London. Parliaments were convened here by the ancient monarchs of England, several of whom occasionally resided in the place.

Tradition says that a convent established here at some period in the sixth century was destroyed in 1016 by Edric. It is certain that in 1043, Leofric and his wife Godgifu (generally, but incorrectly, called Godiva) founded the Benedictine Monastery which was for so many years the prime glory of the city, and the seat of its Bishop's chair.

The name of Godiva will always be associated with the celebrated, but apocryphal, ride, which she is supposed to have made through the streets of Coventry in order to free its people from tolls. Roger of Wendower, writing early in the twelfth century, about 100 years after the event is supposed to have taken place, says: "The Countess "Godiva, who was a great lover of God's mother, longing to free the "town of Coventry from the oppression of a heavy toll, often with "urgent prayers besought her husband, that from regard to Jesus "Christ and His mother, he would free the town from that service, and "from all other heavy burdens; and when the Earl sharply rebuked "her for foolishly asking what was so much to his damage, and "always forbade her for evermore to speak to him on the subject; and "while she, on the other hand, with a woman's pertinacity, never ceased "to exasperate her husband on that matter, he at last made her this "answer: 'Mount your horse and ride naked before all the people, "through the market of the town from one end to the other, and on "your return you shall have your request,' on which Godiva replied; "'But will you give me permission if I am willing to do it?' 'I will,' "said he. Whereupon the Countess, beloved of God, loosed her hair "and let down her tresses, which covered the whole of her body like a "veil, and then, mounting her horse, and attended by two knights, she "rode through the market place without being seen, except her fair "legs, and having completed the journey, she returned with gladness "to her astonished husband, and obtained of him what she had asked, "for Earl Leofric freed the town of Coventry and its inhabitants from "the aforesaid service, and confirmed what he had done by a Charter."

No mention of this ride is made by other and more trustworthy early writers, who narrate the many good deeds which the Earl and Countess

actually performed. It is further discredited by the fact that the population of Coventry in Leofric's time could scarcely have exceeded 350, all in a greater or less degree of servitude, and dwelling probably in wooden hovels, each of a single storey, with a door, but no window. There was, therefore, no market, hardly even a town, through which Godgifu could have ridden, and a mere toll would have been of small moment when the people were all serfs.

The legend of Peeping Tom, that—

> "One low churl, compact of thankless earth,
> The fatal byword of all years to come,
> Boring a little auger-hole in fear,
> Peep'd, but his eyes, before they had their will
> Were shrivell'd into darkness in his head,
> And dropt before him. So the powers who wait
> On noble deeds, cancell'd a sense misus'd,"

was probably tacked on to the story during the reign of Charles II. A figure of Peeping Tom projects from the upper storey of the King's Head Hotel, in Smithford Street. It appears to have been moved to this position from Greyfriars Lane, where it seems to have been originally set up in 1678 by Alderman Owen. The effigy appears to be a figure of Saint George, equipped in armour of the time of Henry VII., and with the arms cut off at the elbows, to favour the posture of leaning out of the window.

At the fair, held on the first Friday of Trinity week, it used to be the custom to celebrate Lady Godiva's ride by a grand procession,

The monastery was amply endowed by Leofric. He gave it half Coventry and twenty-four other lordships in Warwickshire and other counties. So richly was it endowed that William of Malmesbury says that the Abbey "was enriched and beautified with so much gold and "silver, that the walls seemed too narrow to contain it; insomuch, that "Rob. de Limesie, bishop of this diocese in the time of King William "Rufus, scraped from one beam that supported the shrines, 500 marks "of silver."

Leofric died in 1057, and was buried in the Monastery Church, as was his wife Godgifu. She founded the abbey of Stow, near Lincoln, and at her death, the date of which is uncertain, bequeathed all her treasure to the Abbey at Coventry.

Shortly after the Norman Conquest, Coventry became the property of the Earls of Chester by the marriage of Ranulph, with Lucia, grand-daughter of Leofric.

In 1344, Edward III. granted a municipal charter, and the erection of the city walls was commenced a few years after. These were of great strength and extended to a circuit of three miles. They were pulled

down by Charles II. because the city had refused to submit to his father.

In 1397, Richard II. appointed Coventry as the place of combat between the Dukes of Hereford and Norfolk, the lists being arranged at Gosford Green, just outside the town. The combat, however, was prevented by the banishment of the adversaries by the King, a step which eventually led to his own deposition.

When the Duke of Hereford became Henry IV., he held a Parliament here, in the great chamber of the Priory, from which all lawyers were excluded. In 1411, his son (Shakespeare's "Prince Hal") was arrested by the then Mayor, John Horneby, for some disturbance of the peace. It was during this reign also, that Shakespeare makes Falstaff ashamed to march through the town with his regiment of scarecrows with "but a shirt and a half in all the company."

Henry VI. made Coventry a city in 1451, severing it and a district of four miles around from Warwickshire, and converting it into a county of itself, under the name of the City, and the County of the City of Coventry. In 1459, Henry VI. held a Parliament in the Chapter House of the Priory, at which a great number of attainders were passed against the Duke of York and his adherents.

In 1465, Edward IV. and his Queen spent Christmas in Coventry. Five years later, during his struggle with Warwick, the King Maker, he was refused admission to the city. After the battle of Tewkesbury the King revenged himself upon the burghers of Coventry by withdrawing their charter, which was only restored to them after the payment of a fine of 500 marks. Richard III. visited the city. After Bosworth Field Henry VII. visited Coventry and was lodged in the Mayor's house, the citizens presenting him with a gold cup and £100 os. od. Henry VIII. and Queen Katherine visited the city in 1510. The dissolution of the monasteries had a serious effect upon the city. John Hales wrote to the Protector Somerset, "that, in consequence of the dissolution, trade grew "so low, and there was such a dispersion of people from this city, that "there were not above 3,000 inhabitants, whereas formerly there had "been 15,000." Queen Elizabeth visited Coventry in 1565, and was received with splendid pageantry. According to the city manuscripts, in 1566, Mary, Queen of Scots, was a prisoner in the Mayoress's Parlour attached to St. Mary's Hall; and there is a letter dated 1570 from Queen Elizabeth to the Mayor giving instructions for her safe keeping.

In 1610 James I. wrote to the Mayor, Aldermen, and Sheriffs, and the Archdeacon of Coventry, directing the citizens to receive the Sacrament kneeling, and in 1619, when the renewal of the city's charter was asked for, he refused to grant it unless assured that his directions had been complied with.

During the Civil War the city was strongly Parliamentarian. Charles I., in 1614, demanded entrance. The citizens, who had been reinforced by 400 men from Birmingham, offered to admit him and 200 men, but no more. The King had to retire.

After the Restoration, a deputation visited Charles II. and presented him with a basin and ewer of gold with fifty pieces of money, at the same time surrendering to him all the King's lands with the great park. On the day of the Coronation Smithford-street and Cross-Cheaping conduits ran claret; and bonfires were lighted in the evening.

The city was also visited by James II., William III., and Queen Anne.

The trade guilds of Coventry have existed for centuries, and resemble in every respect the city companies of London. Prior to the Reformation, they assisted in the Mystery or Miracle Plays for which the city was famous. The Bakers' Company took part in the first Godiva procession in 1678, when a youth named Swinnerton enacted the part of the Countess In 1892 the same guild—now the Master Bakers' Association—headed the Godiva procession with their banner 200 years old. The Mercer's Guild is regarded as the oldest of those still existing. How long it has been established is not known. It was wealthy and ancient in 1448. The Drapers—founded in the middle of the fourteenth century—is the wealthiest of the existing companies. The books of the guilds contain many interesting entries showing the duties and responsibilities of their members, as well as particulars of the accounts paid for garments and charges incidental to the performance of the Miracle Plays.

St. Mary's Hall, the "Chamber of Princes," was commenced in 1394, finished in 1414, and rebuilt in 1580, It was originally the property of the combined Coventry Guilds. The muniment room contains a singularly valuable and interesting collection of charters and other documents relating to the city. The earliest document in the collection is one from Ranulph, Earl of Chester, in the reign of Henry II. Another document is a mandate of Charles I. to the civic authorities of Coventry, Sutton Coldfield, Stratford-on-Avon, and Birmingham, requiring them to provide a ship of 400 tons burden, with 160 men, and to victual the same. The mandate shows the relative size and importance of the places named at that period. The expenditure was to be divided into fifths, two of which were to be paid by Coventry and one by each of the other towns mentioned. It thus appears that just before the Commonwealth the rateable value of Birmingham was only reckoned as being equal to that of Stratford and Sutton Coldfield. There are also charters from Elizabeth, James I., and Charles II., with portraits of those sovereigns.

The Great Hall is 70 feet long, 30 feet broad, and 34 feet high. It has a fine carved oak roof, and is lit by seven Perpendicular windows.

The chief object of interest in the hall is the magnificent piece of tapestry which hangs on the north wall. It is of Arras manufacture, and was probably made late in the 15th or early in the 16th century, to occupy the position in which it now hangs.

There are a number of portraits in the hall, those of Charles II. and James II., by Lely; and of George III. and George IV., by Lawrence, being noticeable.

The Mayoress' parlour, in which tradition states that Mary Queen of Scots was imprisoned, contains portraits of Queen Mary, by Antonio More, and of Queen Elizabeth, and a picture of Lady Godiva's ride. It also contains a finely-carved oak chair, surmounted by the city arms, the elephant and castle. The earliest mention of this chair is in 1560.

St. Michael's Church is opposite St. Mary's Hall. It is a splendid specimen of Perpendicular architecture, and is one of the most spacious of parish churches in the country. It was chiefly built by the generosity of a family named Botoner, who resided in Coventry in the fourteenth and fifteenth centuries. There used to be a brass plate in the Church which informed the curious that—

> "William and Adam built the tower,
> Ann and Mary built the spire;
> William and Adam built the church,
> Ann and Mary built the quire."

The tower is 136 feet high, and from it rises a lantern, octagonal in shape, 32 feet high, with windows to the four cardinal points, and supported by flying buttresses. The lantern is surmounted by a spire 130 feet high, the total height being 298 feet. The Church is 293 feet 9 inches long, is 127 feet wide, and has five aisles. The roof is of oak.

Holy Trinity Church is close to St. Michael's, and is a fine specimen of a parish Church. There is no evidence as to the date of its foundation. It is first mentioned in 1259. The Church is 178 feet long, and 67 feet wide; it has a wooden roof and a Perpendicular clerestory. The stone pulpit is one of the features of the Church, and the brass lectern is a very early example of a core casting. It is very old, for in 1560 "*x v j d*" were expended for "mendyng of ye Eagle's tayle."

The Cathedral has almost entirely vanished. It was the Priory Church of the Benedictine Monastery, and was the seat of a bishop from 1102 to 1188, when his chair was transferred to Lichfield, the see for many years being described as that of Lichfield and Coventry. The edifice which replaced the original Norman building appears to have been built on the same plan as Lichfield Cathedral. There are a

few remains of it to be seen near Trinity Church, and in the street called New Buildings. The Monastery has disappeared. A public-house, "The Spotted Dog," stands on the site of the gate, and another public-house, "The Pilgrims' Rest," stands on the site of the Hospitium or Guest House of the Monastery at the corner of Palmer Lane.

The spire of Christ Church, 201 feet high, the third of the three tall spires of Coventry, is the only relic of the monastic buildings of the Franciscans, or Grey Friars, who settled in Coventry about 1234.

The site of the Church of St. John the Baptist, in Fleet Street, was given to the Guild of the same name by Isabel, "the she-wolf of France," and the Church was completed in 1350. It was restored in 1877, and is a cruciform building with central lantern tower, and a good window at the west end, of Perpendicular type. The Church forms part of a quadrangle, of which another side is formed by Bonds' Almshouse, founded in 1506, "for ten poore men, so long as the world shall endure, with a woman to look to them."

The front of Ford's Almshouses in Grey Friars Lane is one of the most charming pieces of half-timbered work to be seen in England.

The Carmelite Monastery, or White Friars, near the station, is used as a Workhouse. This order was introduced into Coventry in 1342, and Sir John Poultney, who had been four times Lord Mayor of London, built them a house. After the dissolution it was sold to John Hales, who entertained Queen Elizabeth there at the time of her visit to the city.

Coventry was for long celebrated for its ribbons and watches. Since the decline of those industries, the engineering, cycle, and motor industries have found employment for the nimble fingers and inherited mechanical skill of its people.

WORKS VISITED.

The works of Messrs. Alfred Herbert, Limited, are situated in The Butts, within eight minutes' walk of the station. The various shops have a floor space of 80,700 square feet. The number of workmen is 614, and the number of machine tools is 411.

The following instructions should be adhered to as closely as possible :—

The company will be assembled in the warehouse, and will there be divided into parties of about ten.

Each party will be provided with a guide, who will conduct them round the various departments and give whatever explanations are necessary.

In order to prevent confusion, members are particularly requested to keep with the party to which they are allotted.

Everything in the works is entirely free for inspection, and the guides will be happy to answer questions of any kind.

The following notes point out a few of the most prominent features of the works:—

Warehouse.—This is where machines for stock or awaiting the completion of special tools are stored. Attention is directed to the facility with which goods can be loaded on drays.

Show Room.—This is intended for displaying machines under the most favourable conditions for inspection. It is a three-storey building, and special attention is directed to the arrangement of cranes for placing the machines in position on the galleries. In this department are displayed a large number of samples of customers' work, which have been machined upon turret lathes or automatic screw machines. Attached to each sample is a label giving the time in which it was produced. A careful examination of these samples will be of great interest.

Testing Department.—Here all machines which are ordered with special tool equipments are run and tested upon the actual work for which they are sold before being despatched. In cases where machines are sold upon guarantees, these guarantees are fulfilled in this department in the presence of customers' representatives before the machines are accepted. Attention is directed to the system of inspection of all finished machines, which is carried out by this department.

Fitting Shop.—The erecting and fitting up of the machine tools is sub-divided as far as possible so that one gang of workmen can be kept employed upon the same class of work, enabling a high grade of work to be obtained at a low cost. In this connection it should be noted that separate departments are devoted to the building of headstocks, capstan slides, automatic screw machines, hexagon turret lathes, milling machines, etc. Special attention is directed to the way in which all turrets are bored in position from their own spindles, and to the system of light tramways throughout the works. The drilling machines are situated in this department, and the extensive use of jigs and special fixtures of various kinds should be noted.

Polishing Shop.—All polishing, wherever possible, is done here, no polishing being done upon lathes.

Casting Shed.—Attention is directed to the methods adopted here for pickling castings so as to remove the sand prior to machining.

Turning Departmeut.—There are a large number of ordinary lathes in this department. The following special machines are worthy of attention:—

Cone pulley turning lathes, by means of which all the steps upon a cone pulley are turned and crowned simultaneously, and also all the radial faces.

Vertical boring and turning mill.

Special spindle boring machines for boring out hollow spindles.

Tool Stores.—All loose tools, gauges, milling cutters, etc., are stored here. Attention is directed to the check system used in connection with this department.

Boring Machines.—A large collection of interesting boring jigs can be seen in here; also a special double spindle boring machine for boring the main bearings and the backshaft bearings of headstocks simultaneously.

Planing Machines.—These are of the standard American type. It will be noted that the cutting speed is considerably higher than the usual English practice.

Turret Lathe Department.—This department contains a large collection of turret lathes and capstan lathes of various types, also a complete line of automatic screw machines. Attention is directed to the large number of machines employed upon castings and forgings, and a careful inspection of the work in progress will be of interest. The details of the small tools used on these machines should also be examined.

Regarding machines on bar work. It will be noticed that there are ten automatic screw machines producing all kinds of standard screws, pins, collars, etc., from the bar, and also a number of hexagon turret lathes producing longer pieces.

Attention is directed to the fact that all reductions in diameter on these machines are taken at one cut, and the finish of the work should be especially noted.

Universal Grinding Department.—The machines in this department are mainly of the Brown and Sharpe type. They are employed for finishing all kinds of circular and cylindrical work in mild steel, tool steel, cast-iron, or gun metal.

Drawing Offices.—The main features of interest in this department are the fire-proof strong room in which the drawings are stored, the electric printing apparatus, and the card system by means of which the drawings are indexed and filed.

Stores.—This department is not only used for storing small parts for stock, but also serves as a store for parts of machines in progress. In addition, the stores acts as a control department, and issues all orders to the works. Work is inspected and checked in the stores at various stages during its progress.

It is the duty of the stores to collect and carefully check over the whole of the machined work required for an order before issuing the work to the erecting shop. This ensures that the fitters have everything to hand when commencing to erect a batch of machines.

Milling Department.—Various types of milling machines can be seen here, also many special examples of gang and form milling.

Attention is also directed to the surface grinding machines, metal saws, and saw sharpening machine in this department.

Tool Grinding Department.—Here are made and stored all ordinary turning tools, planer, shaper tools, etc. These tools are made to standard patterns upon the Sellors Grinding machines, two of which are in operation. This department also issues the working drawings to the machine shop.

Small Tool Department.—In this department, in addition to all kinds of small tool work, jigs, fixtures, etc., there is a complete plant of gear-cutting machines.

Spur gears are cut upon the Brown and Sharpe automatics, worm gears upon the Grant worm gear machine, pinions and special spur gears upon the Fellows gear shaper, and bevel gears upon bevel gear planing machines by Reinecker and Gleason. Attention is also directed to the milling machines, to the relieving lathe, the grinding machines on the top floor, and also the precision bench lathe.

The works of the Motor Manufacturing Company, Limited, occupy a large four-storeyed building, besides several detached buildings, running shed, etc. The works are self contained, and every portion of a motor vehicle is made and finished on the premises.

The top floor is entirely devoted to the manufacture of the wooden portions of carriages, and has an equipment of wood-working machinery. Large stocks of various woods are kep .

The third storey is divided into four sections, the first being the coach body painting shop and stoving room for drying the painted and varnished bodies. The second section is devoted to the coachsmiths, who make all the iron portions of the carriage bodies. The third section is the pattern makers' shop. The fourth section is equipped with the machinery necessary for the manufacture of light spirit motors. Every tool is of the latest type and highest efficiency.

The second floor is also divided into sections. In one section small motors are made for attachment to bicycles. In another there is a complete electro-plating plant. The third section is devoted to the manufacture of tangent spoked wheels of various kinds. The fourth section is the tinsmith's and coppersmiths' shop—gear cases, exhaust

boxes, water and fuel tanks, heat radiators, and other parts are made here. The fifth section is the Bollée shop, and is equipped with the latest types of labour-saving machinery. The general offices, managers' and drawing offices are also on this floor.

The heavy machine shop is on the ground floor. All the main parts and gearing of the heavier carriages, and the whole of the powerful motors are made here. In this large shop the motors, gearing, frames, wheels, bodies, and all the other parts forming a perfect carriage are assembled and built up.

The smithy is on the same floor, and is equipped with powerful hammers and complete appliances.

No description of the Daimler Company's works could be obtained, but the whole of the works were thrown open for inspection, and the officials gave the members the opportunity of seeing the various types of motors and vehicles in course of construction or under test.

RULES.

REGISTERED No. 943, WORC.

1.—The Society shall be designated "The Staffordshire Iron and Steel Institute." Its registered office is in England, and is at The Institute, Wolverhampton Street, Dudley, in the County of Worcester. In the event of any change in the situation of the registered office, notice of such change shall be sent within fourteen days thereafter to the Registrar, in the form prescribed by the Treasury Regulations in that behalf.

2.—This Society is subject to the provisions of the Friendly Societies' Act, 1875, except so much thereof as relates to dividing societies (section 11, sub-section 4); the certification of annuities (section 11, sub-section 5); appeals from a refusal to register a society or any amendment of the rules thereof (section 11, sub-sections 8 and 9, and section 13, sub-section 3); or from cancelling or suspension of registry (section 12, sub-section 4 and part of sub-section 5); quinquennial returns and valuations (section 14, sub-section 1, *e f*); certificates of death (section 14, sub-section 2, and section 15, sub-section 9); exemption from stamp duty (section 15, sub-section 2); nomination and distribution (section 15, sub-sections 3, 4, and 5); priority on death, bankruptcy, &c., of officers (section 15, sub-section 7); copyholds (section 16, sub-section 6); loans to members (section 18); the accumulation of surplus of contributions for members' use (section 19); so much of section 22 as relates to the reference of a dispute to the Chief or any other Registrar; the amalgamation, transfer of engagements, and dissolution of Friendly Societies (section 24, priviso to sub-section 8, and section 25, sub-section 1, *c*, and sub-section 7); militiamen and volunteers (section 26); the limitation of benefits (section 27); payments on the death of children (section 28); societies receiving contributions by collections (section 30); cattle insurance and certain other societies (section 31); and the four last heads of Schedule II.

3.—The objects of the Institute are:—To promote the intellectual welfare of its members by periodical meetings for reading and discussing scientific papers on subjects connected with the Iron and Steel Trades, and such other matters as may be considered within the scope of the special authority of 3rd July, 1878 ("The Promotion of Literature, Science, and Fine Arts"). The expenses incurred in carrying out the above objects shall be provided by the subscription of Life and

Honorary Members, the entrance fees and periodical contributions of Ordinary members, and from interest upon any accumulated capital.

CONSTITUTION.

4.—The Institute shall consist of Life, Honorary, and Ordinary Members, who shall be more than twenty-one years of age, and shall be either owners, managers, assistant managers, and other officials of iron and steel works, mechanical or mining engineers, analytical chemists, draughtsmen, or persons of scientific attainments in metallurgy, or specially connected with the application of iron and steel.

HONORARY MEMBERS.

5.—Any person connected with the Iron and Steel Trades may, on the invitation of the Secretary or any other officer, become an Honorary Member of the Institute, on payment of One Guinea yearly to its funds, such payment to entitle him to receive invitations to all meetings of the Institute, and copies of all its publications. Any Honorary Member may become a Hon. Life Member by the payment of Ten Guineas.

ELECTION OF ORDINARY MEMBERS.

6.—Any person desirous of becoming an Ordinary Member of the Institute must be proposed and seconded, as provided by Form A in the Appendix.

7.—The election shall take place at an ordinary meeting; a two-thirds majority of the members present being necessary for election.

8.—When the proposed candidate is elected, the Secretary shall give him notice thereof, according to Form B; but his name shall not be added to the list of members of the Institute until he shall have paid his entrance fee and first annual subscription, and signed Form C in the Appendix.

9.—In the case of non-election, no mention thereof shall be made in the minutes, nor any notice be given to the unsuccessful candidate.

SUBSCRIPTIONS.

10.—The Subscription for an Honorary Member shall be One Guinea per annum, and for an Honorary Life Member Ten Guineas, as provided by Rule 5. Each Ordinary Member shall pay an entrance fee of Two Shillings and Sixpence and an annual subscription of Ten Shillings and Sixpence; or he may become an ordinary Life Member by the payment of Five Guineas. All annual subscriptions shall be payable in advance, and shall be due on the First day of January in each year.

11.—Any member whose subscriptions shall be two years in arrear shall be thereby disqualified, and the Council, after having given due notice, in the Form D in the Appendix, shall remove his name from the list of members, unless satisfactory reasons are given to the contrary.

OFFICERS.

12.—The officers of the Institute shall consist of a President, a Vice-president, Twenty-one Members of Council, Three Trustees, a Treasurer, and a Secretary, who shall be elected at the annual meeting by show of hands. The President, Vice-president, Treasurer, and Secretary shall be *ex-officio* members of the Committee of Management, herein termed Council. Officers may be removed by a special general meeting.

13.—In addition to the *ex-officio* members the Council shall consist of Twenty-one Members, all of whom shall retire annually, but shall be eligible for re-election, with the exception of those who have not attended any of the Council Meetings called during the year for which they have been elected.

14.—The Council shall meet as often as the business of the Institute requires; seven to form a quorum. Such meeting to be called by the Secretary, of which seven clear days' notice shall be given.

15.—The Council shall appoint from its own body two Committees, one to be called the Finance Committee, which shall advise the Council on matters relating to the receipts and expenditure of the Institute; and the other to be called the Publication Committee, which shall arrange for suitable papers to be read at the meetings of the Institute, and shall undertake the revision of all printed transactions. The Council shall provide the Secretary with a sufficient number of copies of the Rules to enable him to deliver to any person on demand a copy of such Rules, on payment of a sum not exceeding One Shilling; and it shall be the duty of the Secretary to deliver such copies accordingly.

DUTIES OF OFFICERS.

16.—The President shall be chairman at all meetings at which he shall be present, and in his absence the Vice-president. In the absence of the Vice-president, the members shall elect a chairman for that meeting.

17.—The Treasurer shall hold in trust the uninvested funds of the Institute, which shall be deposited at a bank approved by the Council; he shall receive from the Secretary all amounts paid by way of subscription, contribution, or payment; and shall pay all accounts that are properly certified as correct by the President and Secretary. He shall keep proper books of account, and shall submit them once a year, or oftener if required by the Council, to the Auditors appointed, and shall supply the Secretary with a duplicate copy of his balance sheet.

18.—The Secretary shall attend all meetings, carry on the general business and correspondence of the Institute, arrange meetings for the reading of papers and for other purposes, and keep minutes of all proceedings, which shall be authenticated by the signature of the Chairman. He shall collect all subscriptions and pay the same to the

Treasurer, and shall prepare and send the Returns required by the Friendly Societies' Acts and the Treasury Regulations to be sent to the Registrar. He shall be paid an honorarium on March 25th in each year, in addition to any sums he may expend on behalf of the Institute for postages, stationery, printing, or travelling expenses.

19.—The Trustees, each of whom must be a householder, and in whose names the properties and surplus funds of the Institute shall be invested, shall continue in office during the pleasure of the Institute, and in the event of any of them dying, resigning, or being removed from office, another or others shall be elected at the next general meeting of the Institute. A copy of every resolution appointing a Trustee shall be sent to the Registrar within fourteen days after the date of the meeting at which such resolution was passed, in the form prescribed by the Treasury Regulations in that behalf.

MEETINGS.

20.—The annual meeting shall be held in April in each year.

21.—General meetings shall be held as often as business requires. The place of such meetings to be decided at the previous annual meeting.

22—The President or the Council, in case he or they at any time think it necessary, or the President, on the requisition of six members, may convene a special general meeting of the Institute, for the consideration of any subject requiring the immediate attention of members. The business of such meeting shall be confined to the special subjects named in the notice convening the same.

23.—All members shall have at least six clear days' notice of, and be entitled to attend, each meeting of the Institute, and to receive copies of the Institute's publications gratuitously.

24.—No alterations of the Rules shall be made except at a general meeting, and four weeks' notice in writing must be given to the Secretary of any proposed alterations. No amendment of Rules is valid until registered.

AUDITORS.

25.—The accounts, together with a general statement of the same, and all necessary vouchers, up to the 31st December then last, shall be submitted once in every year to two auditors appointed by the members at the general meeting preceding each annual meeting, who shall lay before every such meeting a balance sheet (which either may or may not be identical with the annual return, but must not be in contradiction to the same), showing the receipts and expenditure, funds and effects of the Institute, together with a statement of the affairs of the Institute since the last meeting, and of their then condition. Such Auditors shall have access to all the books and accounts of the Institute, and shall examine every balance sheet and annual return of the receipts and expenditure, funds and effects of the Institute, and shall verify the same with the accounts and vouchers relating thereto, and shall either sign the

same as found by them to be correct, duly vouched, and in accordance with law; or shall specially report to the meeting of the Society before which the same is laid in what respects they find it incorrect, unvouched, or not in accordance with law; and the balance sheet or report shall be published in the *Proceedings* of the Institute.

COMMUNICATIONS OF MEMBERS AND OTHERS.

26.—All communications shall be submitted to the Council, and after their approval, shall be read at the general meetings. All communications shall be the property of the Institute, and shall be published only in the *Proceedings* of the Institute, or by the authority of the Council.

PROPERTY OF THE INSTITUTE.

27.—All books, communications, drawings, and the like shall be accessible to all the members. The Council shall have power to deposit the same in such place or places as may be considered most convenient for the members.

INVESTMENT OF FUNDS.

28.—As much of the funds of the Institute as may not be wanted for immediate use, or to meet the usual accruing liabilities, shall, with the consent of the Council, or of a majority of the members of the Institute present at a General Meeting, be invested by the Trustees in such of the following ways as the Council or General Meeting shall direct, namely, in the Post Office Savings Bank, in the Public Funds, or with the Commissioners for the Reduction of the National Debt, upon Government or real securities in Great Britain, or upon the security of any County, Borough, or other rates authorised to be levied or mortgaged by Act of Parliament.

ANNUAL AND OTHER RETURNS.

29.—It shall be the duty of the Committee of Management to keep a copy of the last annual balance sheet of the Society for the time being, together with the Report of the Auditors, if any, always hung up in a conspicuous place at the Registered Office of the Society.—Friendly Societies Act, 1875, s. 14, (1 *i*.).

30.—The books and accounts of the Society shall be open to the inspection of any member or person having an interest in the funds of the Society at all reasonable times, at the registered office of the Society, or at any place where the same are kept, and it shall be the duty of the Secretary to produce them for inspection accordingly.

31.—Every year before the 1st June, the Committee of Management shall cause the Secretary to send to the Registrar the annual return, in the form prescribed by the Chief Registrar of Friendly Societies,required by the Friendly Societies Act, 1875, of the receipts and expenditure, funds and effects of the Society, and of the number of members of the same, up to the 31st December then last inclusively, as audited and laid

before a General Meeting, showing separately the expenditure in respect of the several objects of the Society, together with a copy of the Auditors' Report, if any.

32.—Such return shall state whether the audit has been conducted by a public auditor appointed under the Friendly Societies Act, 1875, and by whom, and if such audit has been conducted by any persons other than a public auditor, shall state the name, address, and calling or profession of each of such persons, and the manner in which, and the authority under which, they were respectively appointed —Friendly Societies Act, 1875, s. 14 (1 *d.*).

33.—It shall be the duty of the Committee of Management to provide the Secretary with a sufficient number of copies of the annual return, or of some balance sheet, or other document duly audited, containing the same particulars as in the annual return as to the receipts and expenditure, funds and effects of the Society, for supplying gratuitously every member or person interested in the funds of the Society, on his application, with a copy of the last annual return of the Society, or of such balance sheet or other document as aforesaid, for the time being, and it shall be the duty of the Secretary to supply such gratuitous copies on application accordingly.—Friendly Societies Act, 1875, s. 14 (1 *h.*).

DISSOLUTION.

34.—The Society may at any time be dissolved by the consent of three-fourths of the members, including honorary members, if any, testified by their signatures, to some instrument of dissolution in the form provided by the Treasury Regulations in that behalf.

DISPUTES.

35 —If any dispute shall arise between a member, or person claiming through a member, or under the Rules of the Society, and the Society, or any officer thereof, it shall be referred to justices pursuant to the Friendly Societies Act, 1875, s. 22 (*c.*)

APPENDIX.

FORM A.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Mr.

of being desirous of becoming a member of the Institute, we, the undersigned, believing him to be fully eligible, hereby recommend him for election.

His qualifications are

Witness our hands this day of 19

} Names of two members.

This application shall be considered by a Committee, consisting of the President and Vice-president (for the time being), and the Secretary, and if they approve of the application, it shall be submitted to a General Meeting for refusal or adoption.

FORM B.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

To

SIR,

I beg to inform you that on the you were elected a member of The Staffordshire Iron and Steel Institute, but in conformity with the Rules, your election cannot be confirmed until the accompanying form be returned with your signature, together with your Entrance Fee and first Annual Subscription. (Amount, £ s. d.)

If this amount be not received in one month from this date, your election will become void.

I am, Sir,

Yours truly,

Secretary.

day of 19

FORM C.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

I, the undersigned, being elected a member of the Staffordshire Iron and Steel Institute, do hereby agree that I will be governed by the rules of the Institute, and that I will advance its interests as far as may be in my power. Provided that if I signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after paying all arrears which may be due by me at that period) be free from thi obligation.

Witness my hand this day of 19

Member's Signature.

FORM D.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

DEAR SIR,

I am directed by the Council to inform you that your subscription to the Institute, amounting to
is still in arrear, and that if the same be not paid to me on or before the
day of your name will be
removed from the lists of the Institute.

Yours faithfully,

Secretary.

OFFICERS FOR SESSION 1902-1903.

President:

WALTER SOMERS, J.P.

Vice-President:

WILLIAM BROOKS.

Trustees:

ALFRED COOKSON, MOSES MILLARD, WILLIAM B. RUBERY.

Treasurer:

JAMES PIPER.

Council:

THOMAS ASHTON
JOHN BATE
JOSEPH BROWN
ALFRED COOKSON
JAMES DONECHAY
DAVID EVANS
W. J. FOSTER
J. W. HALL
WALTER JONES
R. LYTHGOE
MOSES MILLARD
HENRY PARRY
THOMAS PASFIELD
WILLIAM B. RUBERY
HARRY SILVESTER
LEYSHON D. THOMAS
H. B. TOY
ALEXANDER E. TUCKER
T. TURLEY
THOMAS TURNER
WILLIAM YEOMANS

Secretary:

WILLIAM H. CARDER, Tividale Road, Burnt Tree, Tipton.

PAST PRESIDENTS.

1866.—WILLIAM LESTER
1867.—JOHN BROWN
1868.—JOHN WRIGHT
1869.—SAMUEL NEWTON
1870.—WILLIAM EDWARDS
1871.—JOHN FINNEMORE
1872.—AMBROSE BEARDS
1873.—JOHN FIELDHOUSE
1874.—WILLIAM MOLINEAUX
1875.—HENRY HUGHES
1876.—WILLIAM FARNWORTH
1877.—JOHN WRIGHT (second time)
1878.—WALTER HEELEY
1879.—JAMES RIGBY
1880.—EDWARD HARRIS
1881.—JOSEPH MORRIS
1882.—RICHARD EDWARDS
1883.—MOSES MILLARD
1884.—WILLIAM JNO. HUDSON
1885.—RICHARD SMITH CASSON
1886.—HENRY FISHER
1887.—GEORGE B. WRIGHT
1888.—HENRY PARRY
1889.—ALEXR. E. TUCKER
1890.—HERBERT PILKINGTON
1891.—HERBERT PILKINGTON
1892.—THOMAS TURNER
1893.—JAMES ROBERTS
1894.—THOMAS ASHTON
1895.—WILLIAM B. RUBERY
1896.—WILLIAM YEOMANS
1897.—JNO. W. HALL
1898.—H. LE NEVE FOSTER
1899.—HARRY SILVESTER
1900.—LEYSHON D. THOMAS
1901.—WALTER SOMERS

LIST OF MEMBERS.

(CORRECTED TO 29TH SEPTEMBER, 1902).

HONORARY MEMBERS.

Adams, George, and Sons (Ld.).
Mars Ironworks, Wolverhampton.

Akrill, C., and Co., Limited,
Gold's Green Foundry, West Bromwich.

Bayliss, Jones, and Bayliss, Limited,
Victoria Works, Wolverhampton.

Bantock, Thos., and Co.,
Wolverhampton.

Bohler Brothers and Co.,
Pond Hill, Sheffield.

Bradley, T. and I., and Sons,
Darlaston Green Furnaces, Darlaston.

Bromford Iron Co ,
West Bromwich.

Bunch, B., and Sons,
Staffordshire Ironworks, Walsall.

Chatwin, Thomas,
Market Foundry, Tipton.

Cochrane and Co.,
Woodside Ironworks, Dudley.

Dudley, Earl of,
Priory Offices, Dudley.

Fellows, John,
Compton Grange, Cradley Heath, Staffs.

Gilchrist, P. C , F.R.S. (Life),
Frognal Bank, Finchley Road, Hampstead, London, N.W.

Grazebrook, M. and W.,
Netherton Ironworks, near Dudley.

Guest, Josiah, and Sons,
Victoria Foundry. West Bromwich.

Harris Brothers,
Brierley-Hill

Harrison, G. King,
Lye Fire-clay and Brick Works, Stourbridge.

Hickman, A., Limited,
Spring Vale Furnaces, near Wolverhampton.

Hingley, N., and Sons, Limited,
Netherton Ironworks, Dudley.

Hutchinson, W.,
7, Park Road, West, Wolverhampton.

Jones, Walter,
Holly Mount, Red Hill, Stourbridge.

Keay, E. C. and J., Limited,
Prince's Chambers, Corporation-street, Birmingham.

Kirk, Henry,
19. Marsh Side, Workington.

Knight and Crowther, Limited,
Stour Vale Works, Kidderminster.

Knowles, J.,
Wolseley House, Wednesbury.

Langham, J. W.,
Bush Farm Ironworks, West Bromwich.

Lees, Maurice,
Parkbridge Ironworks, Ashton-under-Lyne.

Lilleshall Co., Limited,
Priors Lee Hall, near Shifnal.

Lloyd, F. H., and Co., Limited,
James Bridge Steel Works, near Wednesbury.

Lloyd and Lloyd, Limited,
Coombs Wood Tube Works, Halesowen, Birmingham.

Lones, Vernon, and Holden,
Smethwick, near Birmingham.

McBean, Alexander, J.P.,
Lichfield-street, Wolverhampton.

Parkes, E., and Co.,
Atlas Ironworks, West Bromwich.

Parkes, H. P., and Co., Limited,
Tipton Green Works, Tipton.

Patchett, Colonel Jas.,
Shropshire Iron Co., Limited, Hadley, near Wellington, Salop.

Patent Shaft and Axletree Co., Limited,
Wednesbury.

Pearson, J. H.,
Netherton Furnaces, near Dudley.

Perry, James,
69, Finch Road, Handsworth, Birmingham.

Perry, T., and Son, Limited,
Highfield Works, Bilston.

Punnett, H. M.,
63, Hagley Road, Birmingham.

Reay, John G., J.P.,
Rockingham Hall, Hagley, near Stourbridge.

Roberts and Cooper,
Brierley-Hill.

Roberts, J. and S., Limited,
West Bromwich.

Russell, Jno., and Co., Limited,
Cyclops Ironworks, Walsall.

Siemens, F.,
10, Queen Anne's Gate, Westminster, S.W.

Simpson, F. F.,
Park Lane Ironworks, Oldbury.

Somers, Walter, J.P.,
Belle Vue, Halesowen, Birmingham.

Spencer, John, Limited,
Globe Tube Works, Wednesbury.

Summers, John, and Sons, Limited,
Globe Ironworks, Stalybridge.

Tangyes, Limited,
Cornwall Works, Birmingham.

Taylor and Farley,
Summit Foundry, West Bromwich.

Walker, J. G,
7, Trindle Road, Dudley.

Webb, H. A.,
Church-street Chambers, Stourbridge.

Westley, W.,
Shaw Road, Dudley.

Wilkinson, T. A.,
Minerva Ironworks, Wolverhampton.

ORDINARY MEMBERS.

Allen, Caleb, A. V.,
Philip-street, Coseley, near Bilston.

Allen, Job,
49, Grange Road West Bromwich.

Ashton, T.,
"Branksome," Netherton, near Dudley.

Astbury, J.,
Smethwick Foundry, Smethwick, near Birmingham.

Aston, G. B.,
Clifton Villa, Penn Fields, Wolverhampton.

Attwood, W. W.,
1, Trindle Road, Dudley.

Baker, Alexr. J.,
Grassington, Green-street, Smethwick.

Baker, Wm. T.,
193, Wednesbury Road, Walsall.

Banks, A. R.,
11, High-street, West Bromwich.

Barklam, Geo.,
Burnt Tree, Tipton.

Bate, Jno.,
Bamford House, Haden Hill, Old Hill, Staffs.

Belcher, Joseph,
67, Breeches Road, West Bromwich.

Betts, Thomas,
Jervoise-street, West Bromwich.

Blake, Harry B.,
7, Lea Road, Wolverhampton.

Bloomer, Clifford E.,
Shenstonville, Halesowen, Birmingham.

Bloor, W.,
Portfield, Dudley Port, Tipton.

Booth, Horatio,
Rose Mount, John-street, Wordsley, near Stourbridge.

Broadbent, Thomas,
51, Powke Lane, Old Hill, near Dudley.

Brooks, W.,
17, Wellington Road, Dudley.

Brown, Joseph
Sedgley, near Dudley.

Brown, S. J.,
Gold's Hill Post Office, West Bromwich.

Bryce, D.,
Pensnett, Dudley,

Buchanan, Robert,
35, Thornhill Road, Handsworth, near Birmingham.

Burford, H.,
18, Duncombe-street, Wollaston, Stourbridge.

Burt, Jabez,
40, Dudley Road, West Bromwich.

Burt, Joseph,
43, Grange Road, West Bromwich.

Burton, Wingfield,
Albert House, Bilston.

Carder, W. H.,
Tividale Road, Burnt Tree, Tipton.

Colley, J.,
Hillingdon, Dover-stveet, Bilston.

Cookson, A.,
Coalbournbrook, Stourbridge.

Crofts, D.,
Woodsetton, Dudley.

Darby, Jno W.,
39, Parliament-street, Bury, Lancashire.

Davies, E. Albert,
89, North Road, Wolverhampton.

Davis, Charles H,,
99, Cedar-street, New York City, U.S.A.

Devitt, Michael,
Netherton Furnaces, Dudley.

Donechay, James,
Tipton Green House, Tipton.

Dorsett. William,
Brookdale, Stourport.

Dudley, B J.,
Bromsgrove-street, Halesowen.

Dudley, T. J.,
45, Level-street, Brierley-Hill.

Edwards, R ,
70, Corporation-street, West, Walsall.

Evans, D.,
Plant-street, Old Hill, near Dudley.

Evans, Frederick Edward,
148, Toll End Road, Tipton.

Farnworth, E.,
Broadlands, Goldthorn Hill, Wolverhampton.

Farrington, R. H.,
Station Road, Woodhouse, near Sheffield.

Fieldhouse, J.,
94, St. Paul's Road, West Smethwick.

Fisher, Walter,
Clarence House, Coseley, Bilston.

Flavell, Walter J.,
52, Dudley Road, West Bromwich.

Foster, H. Le Neve,
Athenæum Chambers, Temple Row, Birmingham.

Foster, W. J.,
Arnside House, Gordon-street, Darlaston.

Glaze, George, Ironfounder,
Pensnett, near Dudley.

Gough, William H.,
118, Lord-street, Etruria, Stoke-on-Trent.

Green, B. J.,
Engineer's House, Water and Sewerage Works, Kidderminster.

Green, W. Lloyd,
New Buildings, Sheepwash Lane, Great Bridge, Tipton.

Griffin, Edward B.,
Fullwood's End, Coseley, Bilston.

Growcott, J. W.,
Deercroft House, Portway Road, Oldbury, near Birmingham.

Hall, J. W.,
Athenæum Chambers, 71, Temple Row, Birmingham.

Hammond, H. A.,
Hargate House, West Bromwich.

Hammond, Herbert,
Greenfield House, Cradley Heath, Staffordshire.

Hannah, J. C.,
240, Horseley Heath, Tipton.

Harley, John,
Waterloo Road, North, Wolverhampton.

Harper, A.,
20, Westbourne-street, Stockton-on-Tees.

Harper, Emmanuel,
Cox's Lane, Old Hill, near Dudley.

Harris, E.
New-street, St. George's, near Wellington, Salop.

Hartland, H.,
Ruiton, near Dudley.

Haskew, Frederick J. T.
High-street, Stourbridge.

Haslam, Henry B.,
The Mount, Bank Road, Coseley, Bilston.

Hawkins, W. R.,
The Crown Foundry, Dudley Port, Tipton.

Hedley, R.,
The Poplars, Spennymoor.

Higgs, Charles H ,
60, Reid-street, Crewe.

Higgs, George
21, Aukland Road, Smethwick, Birmingham.

Hodgkiss, Thomas,
King's Hill Villa, Wednesbury.

Holgate, T. E.,
173, Hollins Grove, Darwen.

Howle, W. H.,
16, Bagnall-street, West Bromwich.

Hudson, W. J. (Life),
North Lincolnshire House, Frodingham, Doncaster.

Jacks, T. W. M ,
Hillside, Squire's Walk, Wednesbury.

Jackson, A. W.,
Clay Cross Co., near Chesterfield.

Johnson, Robert,
Chelmer Lodge, Rooth-street, Wednesbury.

Jones, Greville T.,
Clarence Ironworks, Port Clarence, Middlesbro'-on-Tees.

Jones, R. E ,
The Poplars, Whitwell, Mansfield.

Keeling, John.,
Victoria House, Netherton, near Dudley.

Kendrick, W.,
205, Great Bridge-street, West Bromwich.

Knowles, Thomas R.,
Old Park Terrace, Wednesbury.

Legge, A. H.,
Oldswinford, near Stourbridge.

Lennox, L. Gordon, J.P.,
Newbridge Works, Pontypridd.

Lester, Isaac E.,
57, Westminster Road, Handsworth, Birmingham.

Lewis, John,
Caldwall Foundry, Kidderminster.

Lloyd, J. M.,
Cleveland House, Priestfield, Wolverhampton.

Lowcock, Sidney R., M.Inst.C E ,
Temple Courts, Birmingham.

Lycett, J. A ,
Burnt Tree House, Tipton.

Lythgoe, Richard,
Dudley House, Brierley-Hill.

Macartney, Frederick N ,
36, Wainwright Grove, Garston, Liverpool.

McBean, Archibald D. G ,
Tyninghame, Tettenhall, Wolverhampton.

McMillan, W. G.,
8, Leigham Court Road, West, Streatham, London, S. W.

Mantle, H. G., F G.S.,
Old Level Ironworks, Brierley-Hill.

Matchett, James
10, Dial Lane, Hill Top, West Bromwich.

Matty, W. H.,
Langley, near Birmingham.

Meese, Daniel,
" Lonsdale," Toll End Road, Ocker Hill, Tipton.

Mensforth, H.,
11, Nolley Road, Chesterfield.

Meredith, S.,
Tividale Road, Tipton.

Micklewright, William,
Mount House, Mount-street, Walsall.

Millard, Frederick J.,
255, Bloxwich Road, Walsall.

Millard, M.,
Oakleigh, Humber Road, Wolverhampton.

Mills, Frederick,
Ebbw Vale Steel, Iron, and Coal Company, Limited, Ebbw Vale R.S.O., Mon.

Millward, Thomas,
Brantwood, Marlpool Lane, Kidderminster.

Molineaux, W., Jun.,
105, Oxford-street, Bilston.

Moore, Algernon W.,
Spring Vale House. Ettingshall, Wolverhampton.

Moore, Frank,
Lapal Lodge, Quinton, Birmingham.

Moore, William,
Spring Vale House, Ettingshall, Wolverhampton.

Morris, William,
40, Talbot-street, Oldbury.

Mountford, Percy,
Hagley Road, Stourbridge.

Muras, Robert,
83, Darlington-street, Wolverhampton.

Nicholls, James,
Round Oak, Brierley-Hill.

Nicholson, E. D.,
Llynclys, near Oswestry.

Nock, W., Jun.,
Highfields, Bradley, Bilston.

Northwood, Joshua,
109, Oxford-street, Bilston.

Nurse, Frank East,
Eastcroft, Grange Road, West Bromwich.

Oakley, Joseph,
21, Perry-street, Darlaston.

Pagett, W. W.,
Wollaston, Stourbridge.

Parker, Joseph A.,
Dudley Road, Tipton.

Parry, H.,
The Level New Furnaces, Brierley-Hill.

Partridge, H. E.,
13, Carter's Green, West Bromwich.

Pasfield, T.,
24, Wellington Road, Dudley.

Paterson John (Life),
Belle Isle Place, Workington.

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67, Woodland Road, Handsworth, Birmingham.

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Sheepbridge Ironworks, Chesterfield.

Piper, Harold,
The Hawthorns, Collis-street, Amblecote, Stourbridge.

Piper, J.,
The Hawthorns, Collis-street, Amblecote, Stourbridge.

Pool, A.,
Mount Pleasant, Bilston.

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17, Sydney-street, Basford Park, Stoke-on-Trent.

Raybould, James,
Pensnett Road, Brierley-Hill.

Richards, W. H.,
Vulcan Foundry, Darlaston.

Robbins, Jno.,
Sedgley Road, Tipton.

Robbins, W. A.,
Garland Cottages, Neptune-street, Tipton,

Robinson, John,
Beaconsfield Road, Widnes.

Robinson, Philip,
Emerald Villa, Holly Lane, Smethwich, Birmingham.

Rose, T. Lawrence,
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Round, R.,
105, Moor-street, Brierley-Hill.

Rubery, W. B.,
Ashwood, 76, Dudley Road, Tipton.

Rushworth, David,
Clay Cross Ironworks, near Chesterfield.

Scotson, A, Lynn,
Fair View, Wood Green, Wednesbury.

Scott, David,
Inglenook, Penn Fields, Wolverhampton.

Screen, William T.,
Fair View, Horseley Heath, Tipton.

Shakell, W. H. S,
21, St. Dunstan's Road, West Kensington, London, W.

Shedden, Duncan J.,
Dixon's Green, Dudley.

Silvester, H.,
78, Holyhead Road, Handsworth.

Simpson, Brough,
Dixon's Green, Dudley.

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Princes End Foundry, Tipton.

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Somers, William,
Haywood Forge, Halesowen, Birmingham.

Summers, Geo. W.,
Old End House, Coseley, Bilston.

Taplin, Henry,
Furnace Hill, Halesowen, Birmingham.

Thomas, E. F.,
Birchills Ironworks, Walsall.

Thomas, F. G.,
Birchills Ironworks, Walsall.

Thomas, L. D.,
Bromley House, Pensnett, near Dudley.

Thompson, E. S,
Bradley Boiler Works, Bilston.

Thompson, S. J.,
Ettingshall Boiler Works, Wolverhampton.

Toy, Harry B.,
Maiville, Nicholls-street, West Bromwich.

Treglown, C. H.,
38, Wreatham Road, Handsworth, Birmingham.

Tucker, A. E.,
35, Paradise-street, Birmingham.

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"Glenleigh," Woodsetton, near Dudley.

Turner, Professor T., M.Sc., A.R.S.M., F.I.C.,
The University, Birmingham.

Vaughan, Geo. Ed.,
30, Birmingham Road, West Bromwich.

Venables, W. H.,
Farringford, Vicarage Road, Smethwick.

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Redclyffe, Halesowen, Birmingham.

Wassell, Alfred,
Brookvale, House, Denby, near Derby.

Webster, C. W ,
Haden Hill, Old Hill, Staffordshire.

Westwood, Samuel,
Bank Farm, Graveyard Road, Lower Gornal, near Dudley.

Whitehouse, Ernest J.,
77, Dudley Road, Tipton

Whitmore, Samuel,
Faireak Avenue, Newport, Mon.

Whittaker, J. H.,
23, Victoria Terrace, Dudley.

Willcox, Thomas,
314, Stoney Lane, Smethwick, Birmingham.

Williams, A.,

Arnside, Gordon-street, Darlaston.

Williams, G.,

Parkbridge Ironworks, Ashton-under-Lyne.

Winwood, Thomas,

Park Road, Dudley.

Wootton, Thomas,

86, High-street, Blackheath, near Birmingham.

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69	The Influence of Silicon in Cast-iron, W. J. Keep.			
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141	Do. do. do. ... ... 1891, American
142	Do. do. do. ... ... 1892 No. 1.
143	Do. do. do. ... ... 1892 No. 2

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144	Journal of the Iron and Steel Institute .. ... 1893 No. 1.
145	Do. do. do. .. .. 1893 No. 2.
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148	Do. do. do. ... .. 1895 No. 1.
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164	Do. do. do. .. ... 1902 Vol. 1.
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202	Do. do. (National Museum) 1884
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224	Earth Crust Movements and their Causes, Joseph Le Conte.
225	Report of the Naval Court of Inquiry upon the destruction of the U.S. Battleship "Maine" in Havana Harbour, February 15th, 1898.
226	The Rarer Metals and their Alloys, Austen.
227	Bulletin of the Geological Institution of the University of Upsala 1892
228	Do. do. do. 1893
229	Do. do. do. 1894
230	Do. do. do. 1895
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234	Do. do. do. 1899
235	Do. do. do. 1900
251	Transactions of the American Society of Mechanical Engineers 1888

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264	Do. do. do. 1901
275	Papers read before the American Institute of Mining Engineers. 1890
276	Do. do. do. 1891
277	Do. do. do. 1892
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279	Do. do. do. 1894
280	Do. do. do. 1895
281	Do. do. do. 1896
282	Do. do. do. 1897
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301	Transactions of the North of England Institute of Mining and Mechanical Engineers. ... ... Vol. 38
302	Do. do. do. ... Vol. 39
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306	Do. do. do. Vol. 42
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320	Do. do. do. Vol. 51
321	Journal of the West of Scotland Iron and Steel Institute, Vol. I. 1892—94
322	Do. do. do. Vol. II. 1894—95
323	Do. do. do. Vol. III. 1895—96
324	Do. do. do. Vol. IV. 1896—97
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326	Do. do. do. Vol. VI. 1898—99
327	Do. do. do. Vol. VII. 1899—00
328	Do. do. do. Vol. VIII. 1900—01
351	Proceedings of the Nova Scotian Institute of Science .. 1892—93
352	Do. do. do. 1893—94
353	Do. do. do. 1894—95
354	Do. do. do. 1895—96
355	Do. do. do. 1896—97

o.	Work.
6	Proceedings of The Nova Scotian Institute of Science ... 1897—98
7	Do. do. do. 1898—99
8	Do. do. do. 1899—00
1	Transactions of The Royal Scottish Society of Arts, Vol. VIII.
2	Do do. do. Vol. IX.
3	Do. do. do. Vol. X.
4	Do. do. do. Vol. XI.
5	Do. do. do. Vol. XII.
6	Do. do. do. Vol. XIII.
7	Do. do. do. Vol. XIV.
8	Do. do. do. Vol. XV.
1	Metallurgy of Iron, T. Turner.
2	Engineer's and Contractor's Book of Prices, 1895—1896. Spon.
3	Patent Law of all Countries, Thompson.
4	Digest of Physical Tests and Laboratory Practice, No. 1.
5	Do. do. do. No. 2.
6	An Improved Method of Utilising Canals for Traffic, W. B. Cook and F. Willoughby.
7	Digest of Physical Tests and Laboratory Practice, Vol. 2, No. 1.
1	Journal of the Franklin Institute, U.S.A., May, 1895.
2	Do. do. do. June, 1895.
3	Do. do. do. July—December, 1895
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5	Do. do. do. July—December, 1896.
6	Do. do. do. January—June, 1897.
7	Do. do. do. July—December, 1897.
8	Do. do. do. January—June, 1898.
[illegible]	Do. do. do. July—December, 1898.
[illegible]	Do. do. do. January—June, 1899.
1	Do. do. do. July—December, 1899.
[illegible]	Report of Chief Engineer of Manchester Steam Users' Association, May, 1899.
[illegible]	Journal of the Franklin Institute, January—June, 1900.
[illegible]	Do. do July—December, 1900.
[illegible]	Report of Chief Engineer of Manchester Steam Users' Association, May, 1900.
[illegible]	Journal of the Franklin Institute, U.S.A., January—June, 1901.
[illegible]	Do. do. do. July—December, 1901.
[illegible]	Report of Chief Engineer of Manchester Steam Users' Association, June, 1901.
[illegible]	Journal of the Franklin Institute, U.S.A., January—June, 1902.
[illegible]	Subject matter Index of Mining, Mechanical, and Metallurgical Literature for 1900.

INDEX.

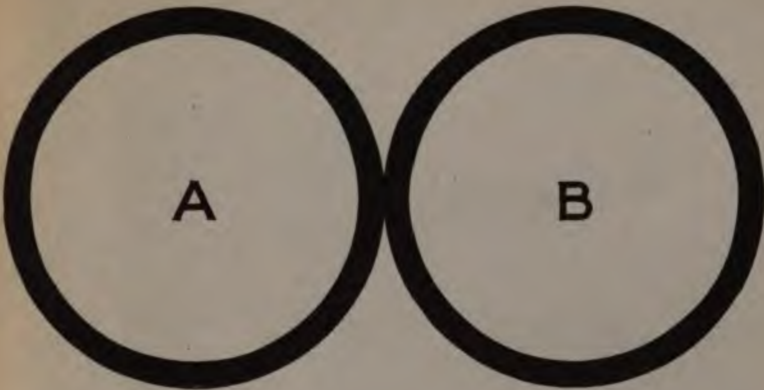


FIG.I.

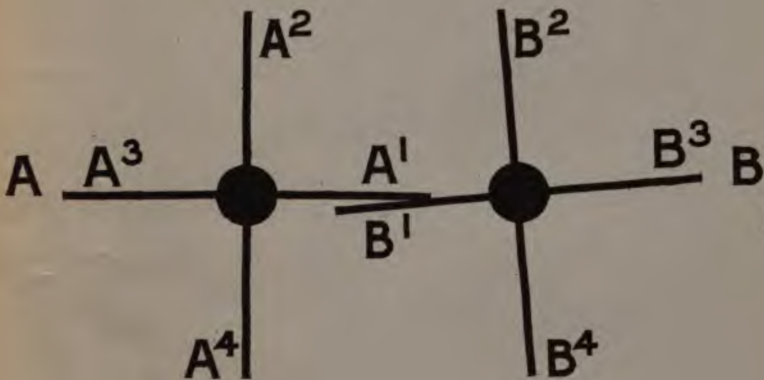


FIG.2.

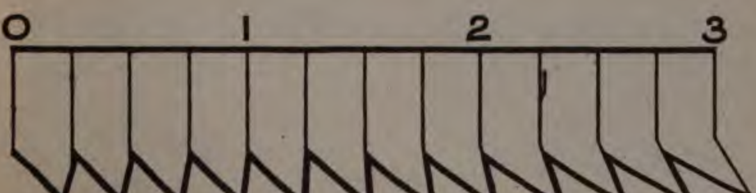


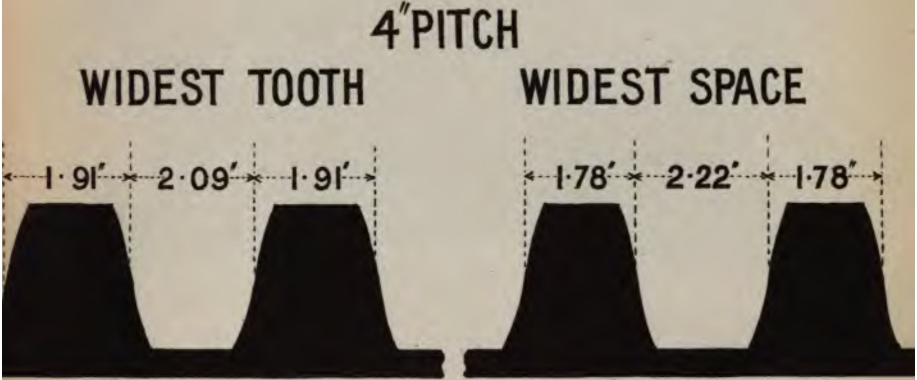
FIG.3

FIG

INVOLUTE

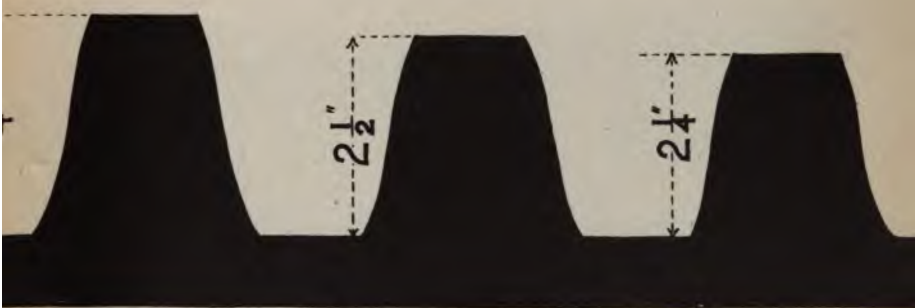
FIG. 4A.

FIG. 9.



3 TEETH EACH 4" PITCH

FIG. 10.



K

FIG. II

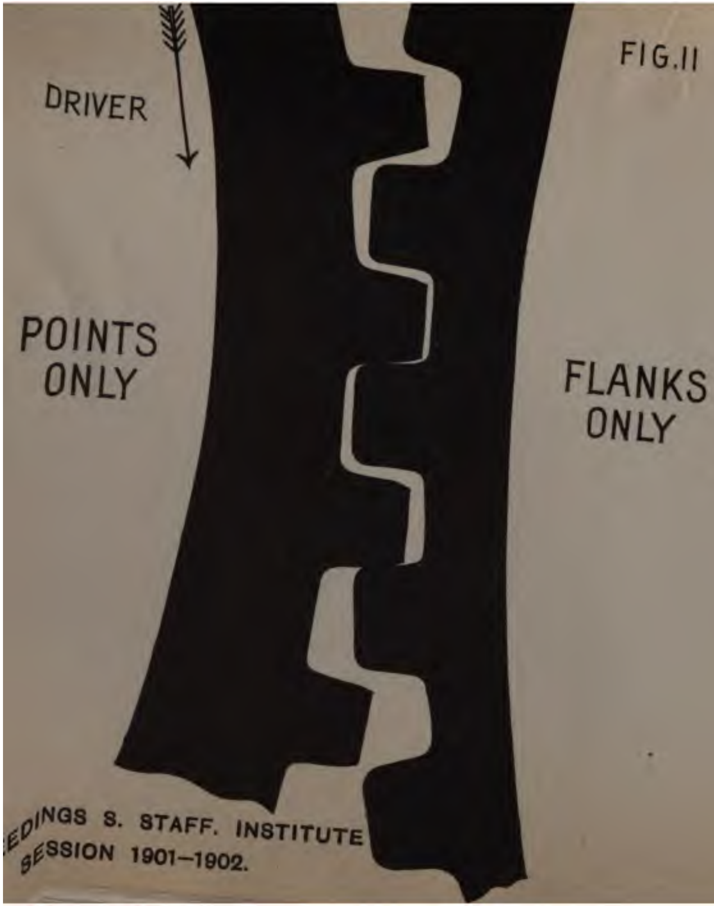


FIG. II A.

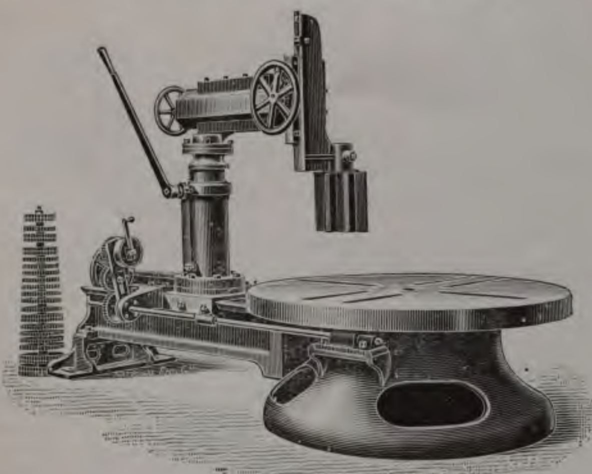
Mr. W. H. .G.

WHEEL-MOULDING]

PROCEEDINGS STAFFS. IRON
SESSION 19C

Mr. W. H. THORNBERY'S PAPER ON WHEEL GEARING.

WHEEL-MOULDING MACHINES BY MESSRS. WILLIAM WHITTAKER & SONS, OLDHAM.



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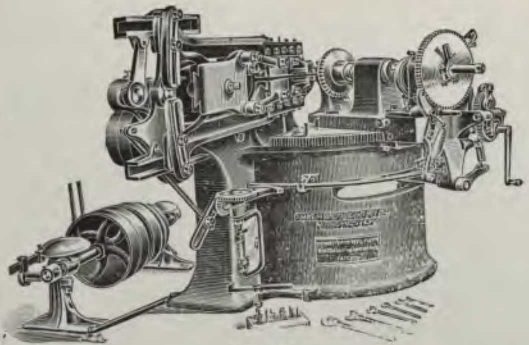
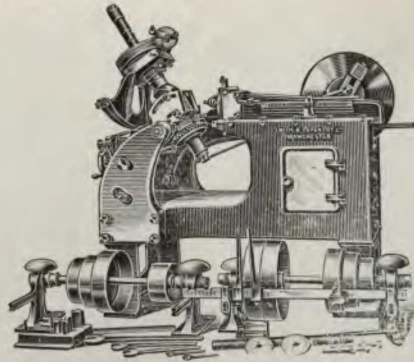
TILDEN FOUNDATIONS

Mr. W. H. THORNBERY'S PAPER ON WHEEL GEARING.

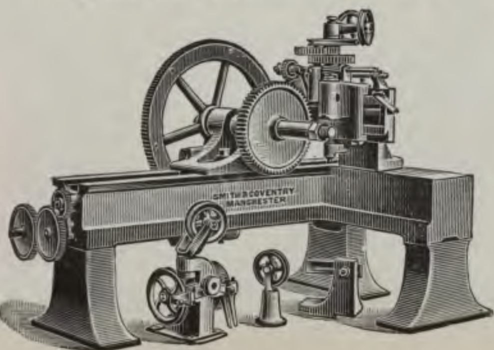


BEVIL.

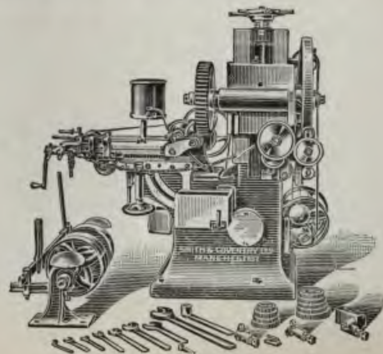


BEVIL.

WHEEL-CUTTING MACHINES BY MESSRS. SMITH & COVENTRY, MANCHESTER.



SPUR.



SPUR.

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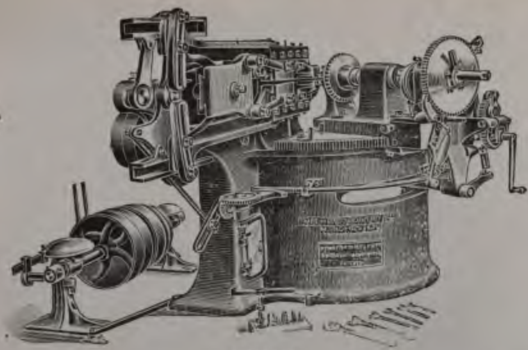
TILDEN

Mr. W. H. THORNBERY'S PAPER ON WHEEL GEARING.



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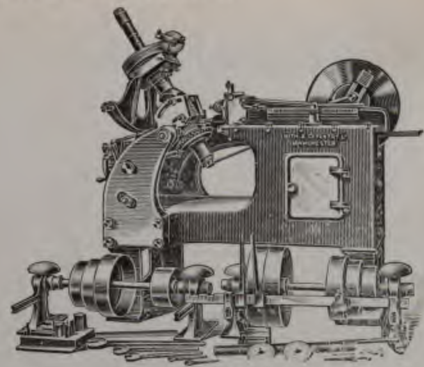
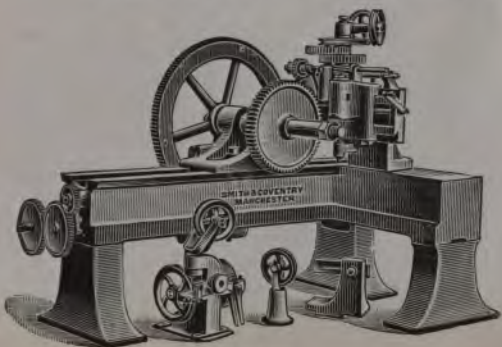
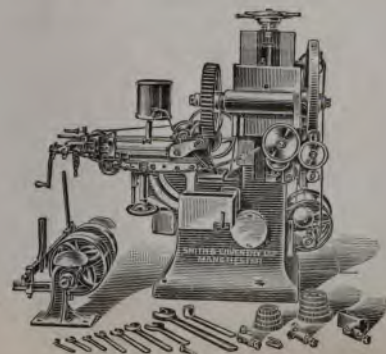


BEVIL.

WHEEL-CUTTING MACHINES BY MESSRS. SMITH & COVENTRY, MANCHESTER.



SPUR.



SPUR.

SPUR WHEEL with CAST-IRON CENTRE & STEEL RIM & FORGED PINION.
17 feet $3\frac{1}{4}$ inches dia. and 4 feet $3\frac{1}{4}$ inches dia. respectively, both 7 inches pitch, 30 inches wide.
The Teeth of both Rim and Pinion milled to correct shape and pitch.

THE SPUR RIM IN ONE PIECE.

WEIGHT OF RIM, 21 TONS; WEIGHT OF CENTRE, 18 TONS.

THE PINION CUT FROM THE SOLID FORGING.

By SCOTT & HODGSON, Ltd., GUIDE BRIDGE.

CAST STEEL SPUR RIM IN ONE PIECE.

17 feet $3\frac{1}{4}$ inches diameter, 7 inches pitch, 30 inches wide.

FINISHED WEIGHT, 21 TONS.

STEEL FORGED PINION 4 feet $3\frac{1}{4}$ inches diameter, CUT FROM THE SOLID FORGING.

TEETH MILLED OUT.

By SCOTT & HODGSON, Ltd., GUIDE BRIDGE.